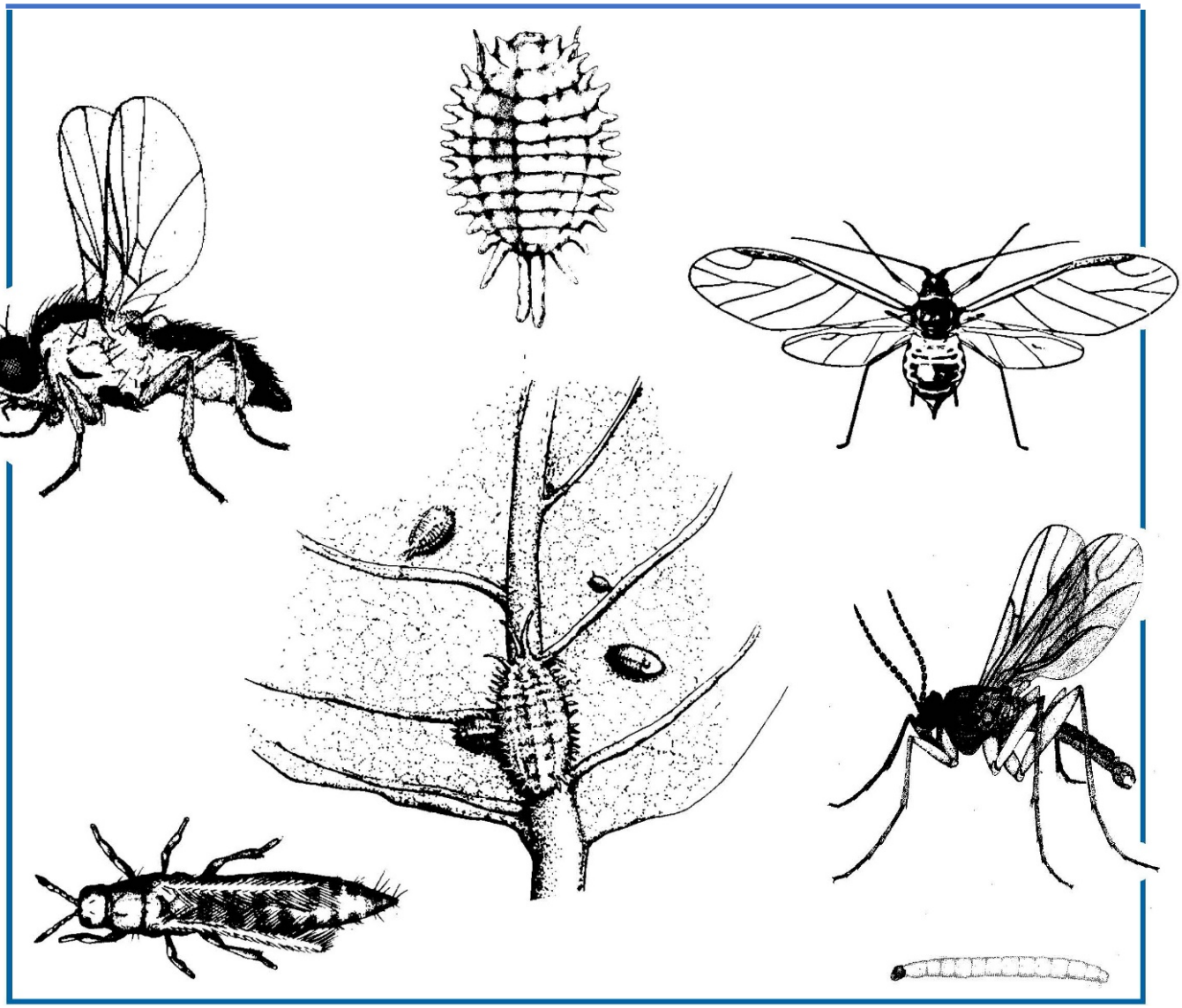
PB 1594

Insect and Mite Pest Management in Greenhouses



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Contents

Insect and Mite Pest Management in Greenhouses

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Pest Management

Integrated Pest Management (IPM) is a term which refers to the use of various strategies to manage greenhouse insect and mite pests. The focus of IPM is to use a variety of management strategies to deal with existing pest problems, rather than relying solely on pest control materials such as insecticides and/or miticides. IPM involves the use of cultural, physical, biological, and/or pesticidal management strategies.

IPM programs typically require producers to be proactive rather than reactive. An effective IPM program begins by regularly scouting the greenhouse crop for insect and mite pests. An IPM program may include establishing action thresholds for specific insect and/or mite pests and then implementing a pest management strategy once a threshold has been reached. Greenhouse producers who have successfully implemented IPM programs indicated that they have reduced costs and increased worker safety. As a result, employees often respond to IPM programs with increased enthusiasm. The objective of this publication is to assist greenhouse producers in starting an IPM program.

Pest Management Basics

Identification

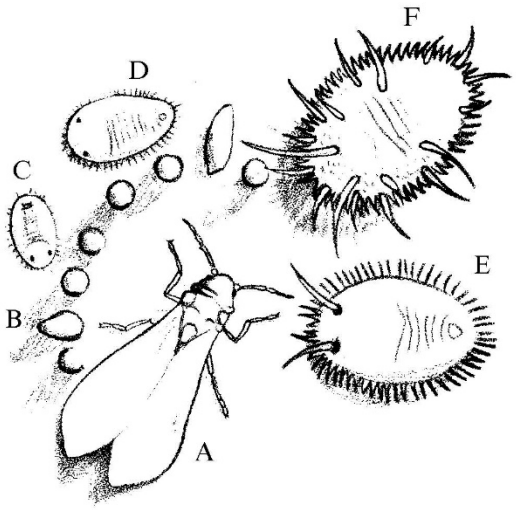
Identifying insect or mite pests and the number of each species in a greenhouse requires diligence, but this information is critical in order for greenhouse producers to avoid spraying an inappropriate pest control material such as an insecticide or miticide. When greenhouse producers know exactly what pests are present and the plants they are present on, then the appropriate insecticide or miticide can be applied. A valuable pictorial guide for pest identification is *Identification of Insects and Related Pests of Horticultural Plants* by R.K. Lindquist and R.A. Cloyd which is published by O.F.A. Services, Inc. The University of Tennessee Soil, Plant and Pest Center in Nashville is another valuable resource.

Sanitation

Clean greenhouses provide fewer opportunities for insect and mite pests to establish and thrive. Weeds in pots or underneath benches serve as reservoirs for many greenhouse insect and mite pests. Weeds underneath benches are not typically sprayed with insecticides and miticides. In addition, many weeds serve as a source for viruses transmitted by insects such as the western flower thrips (*Frankliniella occidentalis)*. Avoid standing water and allow water to properly drain away from the greenhouse since excess water provides an ideal breeding environment for fungus gnats and shore flies. Remove plant

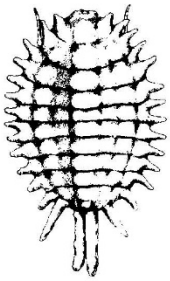
debris and old stock plants from the greenhouse or place into containers with tight-sealing lids because winged adult insects will abandon desiccating plant material and migrate onto the main crop.

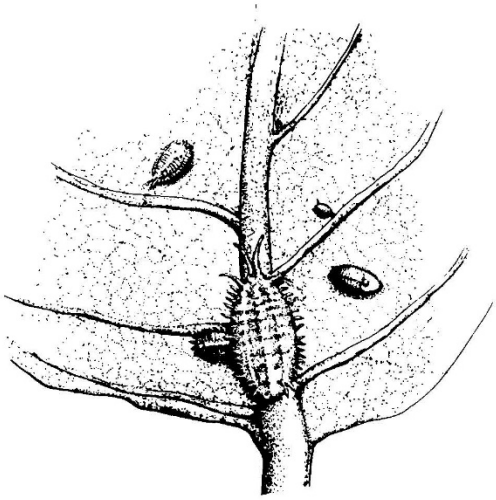
llustrations of Common Insect and Mite Pests of Greenhouse Crops

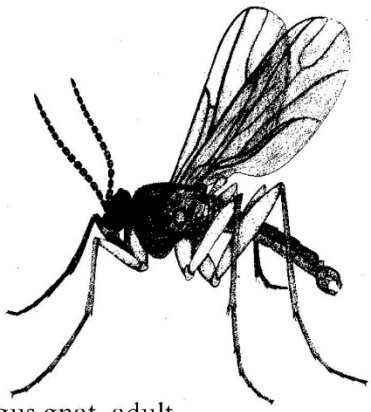


Greenhouse whitefly. A, Adult. B, Eggs. C - E, Nymphs. F, Pupa

Mealybug, adult female



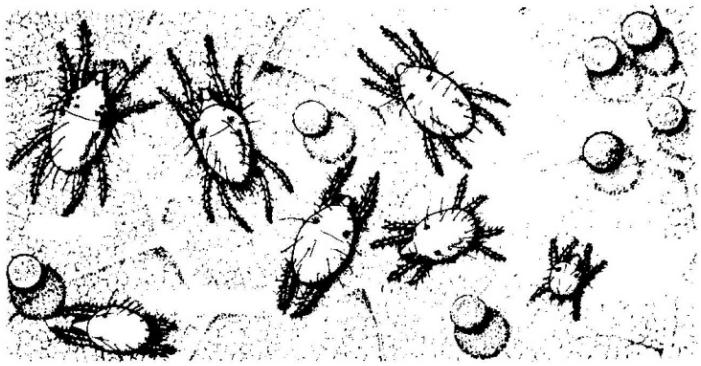




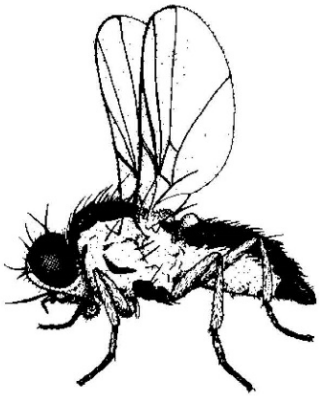
Fungus gnat, adult

Fungus gnat, larva

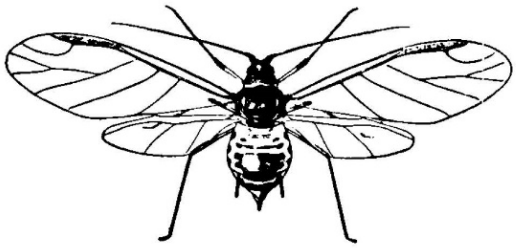
Drawings do not indicate the relative size of the pest; e.g., thrips are much smaller than aphids.



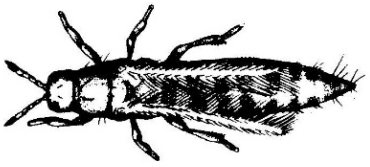
Spider mites



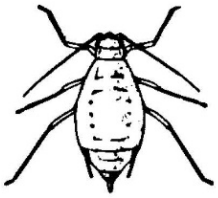
Leafminer, adult



Aphid, winged



Thrips, adult



Aphid

Drawings do not indicate the relative size of the pest; e.g., thrips are much smaller than aphids.

Exclusion

Preventing insect or mite pests from entering the greenhouse is easier than attempting to kill them after they have entered the greenhouse. Many greenhouse producers introduce insect and mite pests into greenhouses when they receive shipments of infested plant material from another source. Carefully inspecting new plants before placing them into a greenhouse can minimize problems with insect and mite pests. Exclusion can also be achieved by screening greenhouse openings, including side and ridge vents with specially designed screening material. Refer to the section entitled “Excluding Insect Pests Using Micro-Screening.”

Management

Once insect or mite pest populations are at or above an action threshold, the application of an insecticide or miticide may be warranted. Insecticides and miticides are expensive, so it is important to select the appropriate product and follow proper application procedures (refer to label). There has been an increase in the use of alternative pest control materials. These materials have relatively low mammalian toxicity and are generally less harmful to biological control agents or natural enemies than most conventional pest control materials. Biological control is the use of natural enemies such as predators, parasitoids and/or pathogens to manage insect or mite pests. Predators consume their prey (host) either partially or entirely while parasitoids lay their eggs inside or on their prey. The immature parasitoid then feeds on the internal contents of the prey. Eventually, the parasitoid matures and the adult either emerges near the dead host or exits from a chewed hole. Pathogens including beneficial fungi and entomopathogenic nematodes work similar to parasitoids since they also consume the inside of a target insect host. Biological control requires considerable management skill and education in order to be successful in commercial greenhouse production systems.

Scouting for Insect and Mite Pests in the Greenhouse

Scouting is a key component in developing a successful IPM program. It is not possible to make pest management decisions without routinely examining sticky cards or visually inspecting plants for the presence of insect and mite pests and determine their numbers. Detecting insect and mite pests when populations are low allows for flexibility in selecting pest management strategies such as removing infested plants or plant parts, using reduced risk insecticides or miticides, and making spot applications to infested plants containing high numbers of insect and mite pests. The following information provides guidance for developing an insect and mite pest scouting program. Line drawings of the key greenhouse insect and mite pests are presented in this publication.

What should be inspected while scouting for pests:

1) Sticky cards

2) Above-ground plant parts such as leaves, stems, and flowers

3) Roots

Sticky Cards

- Place sticky cards just above the plant canopy. Use sticky cards that are 3-by-5 inches.
- Thrips may be more attracted to blue cards; however, yellow sticky cards capture a variety of insect pests including winged aphids, whiteflies, leafminers, fungus gnats and shore flies.
- When scouting for fungus gnat adults, place sticky cards horizontally on pots or on the growing medium surface.
- It is not necessary to count all insects on a sticky card. Select a 1-inch vertical column (not horizontal) and be consistent each time sticky cards are monitored. In addition, one side of a sticky card may be used.
- Place one sticky card per 500 to 1,000 square feet of greenhouse space unless the situation requires the need for more, which will depend on crops grown and virus susceptibility.
- Scout sticky cards weekly, identifying all the insects on sticky cards with a 10X hand lens. Record insect numbers on a worksheet that allows you to monitor changes in populations of individual pest numbers and determine changes in insect and mite pest populations at each location through time.
- Replace sticky cards every week or if they become full of insects, which will make identification difficult.
- Insect pests that may be captured on sticky cards:
    - Whitefly adults
    - Leafminer adults
    - Thrips adults
    - Scale and mealybug adult males
    - Fungus gnat adults
    - Winged adult aphids
    - Shore fly adults
- Insect and mite pests not captured on sticky cards:
    - Non-winged aphids
    - Mites including twospotted spider mite, broad mite and cyclamen mite
    - Mealybug immatures and adult females
    - Scale immatures and adult females
    - Egg, larva/nymph and pupa stages of many greenhouse insect and mite pests

Above-ground Plant Parts and Roots

- Randomly examine plants over an area represented by a sticky card. Pay particular attention to specific plant varieties that are more susceptible to certain insect and mite pests.
- Examine leaf undersides, especially young leaves, for the life stages of whiteflies, mealybugs, aphids, spider mites, and scales.
- Examine the upperside of leaves for:
    - Leafminer tunnels
    - Distortion and discoloration resulting from feeding by thrips, aphids, whiteflies, spider
    - mites, scales, and mealybugs or egg-laying damage from leafminer females.
    - Honeydew a sticky, clear substance excreted by aphids, soft scales, whiteflies and mealybugs.
    - Sooty mold — a dark fungal growth that uses honeydew as a food source.
- Examine terminal growth for immature thrips and aphids.

- Examine open flowers for thrips larvae and adults.
- Examine the main plant stem for scales and mealybugs.
- Look at the base of stems, leaves and other protected crevices for mealybug life stages and immature thrips.
- Examine plant roots for the presence of fungus gnat larvae and root mealybugs.

Pest Thresholds

One principle of IPM is that insect and/or mite pest must be present in numbers that will cause unacceptable crop damage before action should be taken to control the designated insect or mite pest(s). Currently, there are no discreet action thresholds for greenhouse insect and mite pests. However, greenhouse producers usually establish a threshold number based on past experience. Information obtained from scouting records maintained in previous years may help to determine action thresholds for the next season. For example, a greenhouse producer may determine that five adult whiteflies per sticky card per week are acceptable. Therefore, whenever more than five adult whiteflies, on average, are detected on a sticky card for one week, a management strategy should be initiated.

Excluding Insect Pests Using Micro-Screening

Pests can be excluded from greenhouses by placing screens on greenhouse openings including side and ridge vents. The size of the screen mesh is determined by the pests to be excluded. For example, leafminers can be excluded with 0.025-inch mesh screen, whereas western flower thrips require a 0.0075 inch mesh screen.

The two major problems with screening are (1) increased resistance to air flow, which results in reduced cooling capacity in the greenhouse, and (2) protecting the screen from accidental damage by greenhouse equipment or employees.

Placing a screen over greenhouse vents will restrict air movement into the greenhouse, thus reducing the effectiveness of the fans at pulling air through the greenhouse. Properly designed screening is necessary to reduce the effect of the screen on greenhouse cooling. UT Extension faculty can assist you in designing a proper insect screening system. To do so, the following information is required:

Exhaust Fan Information:

Manufacturer

Model No.

Fan Diameter

Power (horsepower)

Number of Exhaust Fans

Greenhouse Floor Area (square feet)

Area of the Vent Opening (square feet)

Extension faculty may need to visit your facility to measure the pressure drop when the fans are turned on. This procedure takes only 30 minutes. With this information, we can determine the area of screen

necessary to avoid severe reduction in the greenhouse cooling capacity, and the possibility of burning out greenhouse fan motors.

Management of Insects and Mite Pests of Greenhouse Crops

Biological Control

Biological control is the use of living organisms to reduce the population levels of insect and mite pests. Biological control agents (natural enemies or beneficials) typically will not entirely eliminate the target insect or mite pest. Some beneficials are capable of surviving on alternate food sources such as pollen, nectar, or other insects and/or mite pests when populations of the target pests are too low to support continued reproduction of the given natural enemy.

A biological control program must be designed for each greenhouse operation based on trial and error. A major challenge is to integrate natural enemies into a pest management program that includes pest control material treatments, which may be harmful to natural enemies. Alternative insecticide and miticides and application techniques are available that are less likely to have detrimental effects on natural enemies. Biological control is more successful when implemented prior to insect and/or mite pest populations having reached damaging levels. As a result, greenhouse personnel must systematically scout for insect and mite pests on a regular basis in order to prevent insect and mite pest populations from reaching damaging levels. Identification and early detection of insect and/or mite pests is important to determine the type of natural enemy or enemies needed and when releases should be implemented in order to maximize effectiveness. Biological control is not a quick fix for control of existing insect and mite pest problems but can be an effective part of a pest management program in which the goal is to reduce reliance on insecticides and miticides.

Types of Commercially Available Biological Control Agents

The larvae and/or adults of predators including the ladybird beetle, green lacewing, and minute pirate bug have a particular prey preference and require certain environmental conditions such as temperature and relative humidity to be successful (see Table 1). Parasitic wasps or parasitoids are host-specific and in general they tend to attack only one type of insect pest or life stage. In addition, they may be stage-specific meaning that parasitoids will insert their eggs into the eggs or other life stages such as larvae or adults of certain insect pests. Immature parasitoids feed in or on the host, eventually killing it. Entomopathogenic nematodes are soil-dwelling, microscopic roundworms that enter insect hosts can emit a bacterium lethal to insect hosts; killing them within 48 hours.

The entomopathogenic nematodes enter an insect through natural openings such as the mouth, anus, or spiracles (breathing pores), and regurgitate bacteria which paralyze and kill the insect host. The entomopathogenic nematodes feed on the reproducing bacteria and continue to multiply in the insect carcass, eventually exiting to find a new host after the food source dissipates.

Table 1. Biological Control Agents of Insect and Mite Pests of Greenhouses

Pests	Predators	Comments	Parasitoids and Entomopathogenic Nematode	Comments
Aphids	Lacewings, *Chrysoperla* spp. and *Chrysopa* spp.	Release as eggs or larvae. Feed on several different insect and mite pests in the absence of aphids.	Parasitoid, *Aphidius colemani*	Effective against green peach and melon aphid.
	Aphid midge, *Aphidoletes aphidimyza*	Adults do not feed. Only the larvae are predacious. Inactive during short days unless light is provided.	Parasitoid, *Aphelinus abdomalis*	Effective against potato aphid.
	Ladybird beetle, *Hippodamia convergens*	Adults and larvae are predacious. Feed on different aphid species.	Parasitoid, *Aphidius ervi*	Effective against potato and foxglove aphid.
Fungus gnat larvae	Predatory mite, *Stratiolaelaps scimitus* (formerly *Hypoaspis miles*)	Soil predatory mite that resides in growing medium. Seven to 11 day life cycle. Can incorporate into growing media before filling containers. May be used in conjuction with *Bacillus thuringiensis* subsp. *israelensis*, and entomopathogenic nematodes.	Entomopathogenic nematode *Steinernema feltiae* (Scanmask, Entonem, Nemasys, and NemaShield)	Attacks fungus gnat larvae.
	Rove beetle, *Dalotia coriaria*	Both adult and larvae are predacious. Feed on fungus gnats larvae and western flower thrips pupae.		
Leafminer larvae			Parasitoids: *Dacnusa sibirica* and *Diglyphus isaea*	Parasitoid larvae complete development inside or outside leafminer larvae. Optimial temperatures for development vary between the two parasitoids.
Mealybugs	Mealybug destroyer, *Cryptolaemus montrouzieri*	Feeds on all mealybug life stages. Primarily effective when mealybug populations are high. Less effective when exposed to low light conditions.		

Pests	Predators	Comments	Parasitoids and Entomopathogenic Nematode	Comments
Mites	Predatory mite, *Phytoseiulus persimilis*	Requires temperature <80ºF and relative humidity between 60% to 80%. Only feeds on twospotted spider mite.		
	Predatory mite, *Mesoseiulus longipes* (formerly *Phytoseiulus longipes*)	Tolerates warmer temperatures and a lower relative humidity than *P. persimilis.* Used for regulation of twospotted spider mite populations.		
	Predatory mite, *Neoseiulus* (formerly *Amblyseius*) *californicus*	Survives longer without prey than *P. persimilis* . Used for regulation of twospotted spider mite, broad mite and cyclamen mite.		
	Predatory midge, *Feltiella acarisuga*	Feeds on twospotted spider mites. Only larvae are predaceous as adults do not feed.		
	Predatory mite, *Neoseiulus* (formerly *Amblyseius*) *fallacis*	Effective against twospotted spider mite		
	Galendromus (formerly *Metaseiulus*) *occidentalis*	Effective against twospotted spider mite, broad mite, cyclamen mite, and tomato russet mite		
	Amblyseius andersoni	Effective against twospotted spider mite, tomato russet mite, and broad mite		
Scales	Ladybird beetle, *Lindorus or Rhyzobius lophanthae*	The adult and larva attack hard (armored) and soft scales.	Parasitoid, *Aphytis melinus*	Only attacks certain hard (armored) scales.

Pests	Predators	Comments	Parasitoids and Entomopathogenic Nematode	Comments
			Parasitoid, *Metaphycus helvolus*	Only attacks certain soft scales such as brown soft scale. However, brown soft scale can encapsulate eggs.
Thrips	Predatory Mite, *Amblydromalus limonicus*	Effective against thrips larvae as well as whitefly eggs and larvae.		
	Predatory Mite, *Neoseiulus* (formerly *Amblyseius*) *cucumeris*	Only attacks first instar larvae. Can survive on pollen in the absence of prey.		
	Predatory Mite, *Stratiolaelaps scimitus* (formerly *Hypoaspis miles*)	May feed on western flower thrips pupae in growing media. Can be incorporated into growing media.		
	Insidious flower bug, *Orius insidiosus*	The adult and nymphal stages are predacious. Survives on pollen in the absence of prey. Also feed on aphids, spider mites, and whiteflies.		
	Predatory Mite, *Amblyseius swirskii*	Effective against western flower thrips and whiteflies.		
Whiteflies	Ladybird beetle, *Delphastus catalinae*	Both adult and larvae feed on eggs and nymphs. Requires 'high' whitefly populations for survival.	Parasitoid, *Encarsia formosa*	Primarly used against greenhouse whitefly. Prefers temperatures >72 F. Adults lay eggs in second instar nymphs and feed on third instar nymphs.

	Predators	Comments	Parasitoids and Entomopathogenic Nematode	Comments
			Parasitoid, *Eretmocerus eremicus*	Primarily used against sweet potato whitefly.
	Predatory Mite, *Amblydromalus limonicus*	Effective against whitefly eggs and larvae as well as thrips larvae.		
	Predatory Mite, *Amblyseius swirskii*	Effective against whiteflies and western flower thrips.		

Alternative Pest Control Materials

Alternative pest control materials, in this case insecticides and miticides, are those that, in general, have activity on specific target insect or mite pests while being less harmful to natural enemies. Proper timing of applications is important in order to control specific insect or mite pests.

Insect growth regulators

Insect growth regulators or IGRs are used to kill the young (immature) stages of plant feeding insects including mealybugs, scales, and whiteflies. Insect growth regulators regulate insect development and are typically placed into three general categories: juvenile hormone mimics or analogs; ecdysone antagonists; and chitin synthesis inhibitors. Juvenile hormone mimics or analogs inhibit development and cause insects to remain in an immature stage thus preventing insects from completing their life cycle. Ecdysone antagonists disrupt the molting process of insects by inhibiting metabolism of the molting hormone ecdysone. Chitin synthesis inhibitors interfere with enzymes during the molting process that stimulate the synthesis and formation of chitin, an essential component of an insect's exoskeleton. As a result, insects fail to reach adulthood because they die in an immature stage, or they mature into sterile adult females.

Microbials

These are insecticides containing microorganisms such as bacteria or fungi which cause diseases of insects. They are usually very specific for the targeted insect pest and are slow-acting typically requiring repeat applications. *Bacillus thuringiensis* (Bt) is an example of a toxin-producing bacteria used against the larval stage of moths (caterpillars) and fungus gnats. *Beauvaria bassiana* is a fungal pathogen or entomopathogenic fungus used against aphids, mites, thrips, and whiteflies. Spores (conidia) of the fungus germinate on the surface of the insect and hyphae penetrate the cuticle. Similar to parasitoids, the fungus consumes the internal contents of the host. In addition, the insect dies from a toxin produced by the fungus.

Neem products

These insecticides are based on extracts from the tropical and subtropical neem tree, *Azadirachta indica*. Azadirachtin, the most commonly used material is derived from the oil of neem tree seeds. It acts as an insect growth regulator, insect feeding deterrent, repellent, oviposition inhibitor, sterilant, and/or direct toxin. The other material derived is the clarified hydrophobic extract of neem oil, which suffocates and desiccates insect and mite pests. Neem oil has contact activity only so thorough coverage of all plant parts is important.

Horticultural oils

These are petroleum or plant-based materials that suffocate insect and mite pests by blocking the breathing pores (spiracles) and disrupting cell membranes. Horticultural oils have short residual activity.

Insecticidal soaps

These are derivatives of potassium salts of fatty acid chains that act by disrupting insect cell membranes. Insecticidal soaps have a short residual activity.

Selective feeding blockers

These materials inhibit the feeding behavior of insects by interfering with neural regulation of fluid intake through the mouthparts. Insects starve to death within 48 hours.

Conventional Pest Control Materials

Selecting a Pest Control Material

Once a perceived pest threshold has reached, then pest control material (insecticide or miticide) applications may be initiated. A pest control material choice is dictated by:

- Effectiveness on the existing insect or mite pest(s)
- Mode of action
- Application method
- Human toxicity
- Potential phytotoxicity
- Potential impact on non-target organisms including natural enemies
- Cost
- Restricted entry interval (REI)

Table 2 lists insecticides and miticides labeled for control of insect and mite pests in greenhouses.

Table 2. Pest Control Materials Labeled for Use in Greenhouses for Control of Insect and Mite Pests

PESTICIDE	APHIDS	LEAFMINERS	FUNGUSGNATS	WHITEFLIES	MITES	THRIPS	SCALE	CATERPILLARS	MEALYBUGS	CLASS	REI (hr)	IRAC*	COMMENTS
Adept (diflubenzuron)		X	X	X				X		IGR	12	15	Primarily active on immature stages with long residual activity. Can be applied as a spray or drench. For lepidoptera leafminers, not diptera leafminers.
Akari 5SC (fenpyroximate)					X					PP	12	21A	Primarily active on larval stages. Provides up to 21 days of residual activity. Does not have translaminar properties.
Altus (flupyradifurone)	X			X		X			X	BU	4 (12 for CA)	4D	Provides suppression of citrus leafminer and scale.
Ancora *(Isaria fumosorosea Apopka Strain 97, ATCC 20874)*	X	X		X	X	X			X	MI	4	Unclassified	Insect-killling fungus. Contact activity only so thorough coverage of all plant parts is important. Make applications in the evening.
Aria (flonicamid)	X			X					X	OR	12	29	Selective feeding blocker that prevents insects from feeding. Systemic insecticide with translaminar activity.
Attain (bifenthrin)	X		X	X	X		X	X		PY	12	3A	Thorough coverage is necessary to contact insect and mite pests. Treat late in day and vent before entry.
Avid (abamectin)	X	X		X	X	X				ML	12	6	Do not apply to ferns or Shasta daisy. Insecticide/miticide derived from soil microorganisms, with translaminar activity.
Azatin (azadirachtin)	X		X	X				X		BO	4	Unknown	Insect growth regulator so only active on immature stages of most insect pests. Has multiple modes of action. Slow acting. Repeat applications may be needed after 7 to 10 days.

PESTICIDE	APHIDS	LEAFMINERS	FUNGUSGNATS	WHITEFLIES	MITES	THRIPS	SCALE	CATERPILLARS	MEALYBUGS	CLASS	REI (hr)	IRAC*	COMMENTS
Azatrol (azadirachtin)	X		X	X		X	X	X	X	BO	4	Unknown	Insect growth regulator so only active on immature stages of most insect pests. Repeat applications may be needed after 7 to 10 days. May be tank-mixed with other insecticides.
BotaniGard ES, 22WP (*Beauveria bassiana*)	X			X		X				MI	4	Unclassified	Insect-killing fungus. Need to apply before insect populations reach outbreak levels. Requires relative humidity >65%. Do not use thermal pulse fogger for low-volume applications. Thorough coverage of all plant parts is important. Make applications in the evening.
Citation (cyromazine)		X	X							IGR	4	17	Insect growth regulator so only active on immature stages. Labeled for use against diptera leafminer and fungus gnat and shorefly larvae.
Conserve (spinosad)		X				X		X		MI + SP	4	5	Provides rapid knockdown of thrips populations. Rotate with other insecticides with different modes of action to avoid resistance. Also labeled for use against leafminers and caterpillars.
Decathlon (cyfluthrin)	X		X	X		X	X	X	X	PY	12	3A	Has contact activity only so thorough coverage of plant parts is important. May be directly harmful to natural enemies.
Dibrom 8 (naled)	X			X	X		X	X		OP	24	1B	Avoid making applications to wandering jew, poinsettia, Dutchmans Pipe and chrysanthemums due to potential for plant injury (phytotoxicity).

PESTICIDE	APHIDS	LEAFMINERS	FUNGUSGNATS	WHITEFLIES	MITES	THRIPS	SCALE	CATERPILLARS	MEALYBUGS	CLASS	REI (hr)	IRAC*	COMMENTS
Dipel Pro DF (*Bacillus thuringiensis* subsp. *kurstaki*)								X		MI	4	11A	Target insect must ingest this material in order to be killed. Feeding stops immediately with death occurring in 2 to 3 days. Thorough coverage of all plant parts is important. Not directly harmful to most natural enemies.
Discus L (imidacloprid + cyfluthrin)	X	X	X	X		X	X	X	X	NN+PY	12	4A + 3A	Fungus gnat larvae in the growing medium/soil will be controlled by drench applications or growing medium incorporation. Thrips suppression on foliage only. Effective on soft scales with suppression only for hard (armored) scales. Target scale crawlers when making foliar applications. Caterpillar control when applied to foliage.
Distance IGR, Fulcrum (pyriproxyfen)			X	X			X			IGR	12	7C	Has translaminar activity. Do not apply to poinsettia after bract development. May be effective against western flower thrips pupae when applied as a drench to the growing medium/soil.
DuraGuard (chlorpyrifos)	X		X			X	X	X		OP	24	1B	Micro-encapsulated formulation. May be applied as a spray or drench to the growing medium/soil. Thorough coverage of all plant parts is important when applied to the foliage.
Duraplex (chlorpyrifos + cyfluthrin)	X		X	X		X		X		OP+PY	24	1B + 3A	Controls fungus gnat adults and is most effective against insect pests when plants are small.

PESTICIDE	APHIDS	LEAFMINERS	FUNGUSGNATS	WHITEFLIES	MITES	THRIPS	SCALE	CATERPILLARS	MEALYBUGS	CLASS	REI (hr)	IRAC*	COMMENTS
Endeavor (pymetrozine)	X			X						PDZ	12	9B	Selective feeding blocker that prevents insects from feeding. Has both systemic and translaminar activity. Not directly harmful to most natural enemies.
Enstar AQ (kinoprene)	X		X	X		X	X		X	IGR	4	7A	Insect growth regulator so most active on immature stages of certain insects. Slow acting so repeat applications will be needed.
Flagship 25 WG (thiamethoxam)	X	X		X			X		X	NN	12	4A	Systemic insecticide with translaminar properties. Has extended residual activity. Only effective on soft scales, not hard (armored) scales.
Floramite SC (bifenazate)					X					CARB	4	20D	Only active on spider mites. Contact activity only so thorough coverage of plant parts is important. Provides up to four weeks of residual activity. Minimal direct effect on most predatory mites.
Gnatrol (*Bacillus thuringiensis* subsp. *israelensis*)			X							MI	4	11A	Larvae must ingest material to be killed. Feeding stops immediately with death occurring in 3 to 5 days. Works best on the early larval instars. Not directly harmful to most natural enemies.
Hachi-Hachi SC (tolfenpyrad)	X			X		X	X			CBOX	12	21A	Contact activity only so thorough coverage of all plant parts is important. Does not have translaminar properties.

PESTICIDE	APHIDS	LEAFMINERS	FUNGUSGNATS	WHITEFLIES	MITES	THRIPS	SCALE	CATERPILLARS	MEALYBUGS	CLASS	REI (hr)	IRAC*	COMMENTS
Hexygon (hexythiazox)					X					CBOX	12	10A	Provides up to 30 days of residual activity. Only kills the egg and larval stages with no effects on adult spider mites. Only one application is allowed per cropping cycle to avoid resistance issues.
Insecticidal Soap (potassium salts of fatty acids)	X			X	X	X	X		X	SO	4	Unclassified	Contact activity only so thorough coverage of all plant parts is important. Avoid applying more than three times in succession or plant injury (phytotoxicity) may result. Has short residual activity so repeat applications will be needed.
Intrepid 2F (methoxyfenozide)								X		IGR	4	18	
Kontos (spirotetramat)	X			X	X	X			X	TA	24	23	Has systemic activity against mites when used preventatively.
Magus (fenazaquin)				X	X					QUIN	12	21A	Contact activity only so thorough coverage of all plant parts is important. Does not have translaminar properties.
Mainspring, Mainspring GNL (cyantraniliprole)				X		X	X	X		AD	4	28	Has systemic activity. For soft scale only. Aphids on Mainspring GNL label only, not Mainspring label.
Marathon (imidacloprid)	X	X	X	X		X	X		X	NN	12	4A	Systemic insecticide with translaminar properties. Has extended residual activity. Effective on soft scales but not hard (armored) scales.

PESTICIDE	APHIDS	LEAFMINERS	FUNGUSGNATS	WHITEFLIES	MITES	THRIPS	SCALE	CATERPILLARS	MEALYBUGS	CLASS	REI (hr)	IRAC*	COMMENTS
Mavrik Aquaflow (fluvalinate)	X			X	X	X	X	X		PY	12	3A	Contact activity only so thorough coverage of all plant parts is important. May cause respiratory allergic response.
Mesurol (methiocarb)	X					X				CA	24	1A	Thorough coverage of plant parts is important. Can also be used for control of slugs and snails. May leave distinct residues on plant leaves.
Met52 EC (*Metarhizium anisopliae* strain F52)				X	X	X				MI	0 for soil incorporated mechani-cally, 4 for all other uses	Unclassified	Insect killing fungus. Thorough coverage of all plant parts is important
Molt-X (azadirachtin)	X		X	X		X	X	X	X	BO	4	Unknown	Insect growth regulator so only active on immature stages of most insect pests. Slow acting. Make repeat applications after 7 to 10 days. Can be tank-mixed with other insecticides.
M-Pede (potassium salts of fatty acids)	X			X	X	X	X		X	SO	12	Unclassified	Contact activity only so thorough coverage of all plant parts is important. Has short residual activity so repeat applications will be needed. However, do not apply more than twice in succession to avoid foliar discoloration.
Nemasys, ScanMask, Entonem, NemaShield (*Steinernema feltiae*)			X							B	0	Unclassified	Only active on fungus gnat larvae. Apply before fungus gnat larval populations reach outbreak levels. Two to three applications may be needed.

PESTICIDE	APHIDS	LEAFMINERS	FUNGUSGNATS	WHITEFLIES	MITES	THRIPS	SCALE	CATERPILLARS	MEALYBUGS	CLASS	REI (hr)	IRAC*	COMMENTS
NoFly WP (*Isaria fumosoroseus*)	X			X		X			X	MI	4	Unclassified	Insect killing fungus. Contact activity only so thorough coverage of all plant parts is important. Apply before pest populations reach outbreak levels.
Novato (Ovation/Applause) (clofentezine)					X					TET	12	10A	Only active on spider mite eggs and early mite life stages. Can only use once per cropping cycle. Most effective when applied at the first sign of mite activity and when females are laying eggs.
Ornazin (azadirachtin)	X		X	X				X		IGR	12	Unknown	Insect growth regulator so most active on immature stages. Slow acting so repeat applications will be needed. Requires a spray solution pH between 4 and 8.
Orthene (acephate)	X	X		X		X	X	X	X	OP	12	1B	Has systemic and translaminar activity. May be harmful (phytotoxic) to certain plants, including chrysanthemum cultivars. Wait two weeks for symptoms to appear. Can be tank mixed with fenpropathrin (Tame) to enhance control of thrips.
Orthene 1300 (acephate)	X	X	X	X		X	X	X	X	OP	24	1B	Has translaminar activity. May be harmful (phytotoxic) to certain plants, including chrysanthemum cultivars. Wait two weeks for symptoms to appear. Treat as late in day as possible and vent before re-entry.
Overture (pyridalyl)						X		X		Unclass-ified	12	Unknown	Has contact and translaminar activity. May take up to 10 days to effectively suppress thrips populations.

PESTICIDE	APHIDS	LEAFMINERS	FUNGUSGNATS	WHITEFLIES	MITES	THRIPS	SCALE	CATERPILLARS	MEALYBUGS	CLASS	REI (hr)	IRAC*	COMMENTS
Pedestal (novaluron)		X		X		X		X		IGR	12	15	Insect growth regulator so only active on immature stages. May sterilize adult female whiteflies. Only provides suppression of leafminers.
Perm-Up (permethrin)	X	X	X	X			X	X		PY	24	3A	Contact activity only so thorough coverage of all plant parts is important. May be harmful (phytotoxic) to *Salvia* spp. with marginal leaf burn and necrosis of open petals. Used primarily for control of leafminer adults.
Precision (fenoxycarb)	X	X	X				X			IGR + CA	12	7B	Insect growth regulator so only active on immature stages. Repeat applications will be needed. For caterpillar leafminers, not fly leafminers.
Preclude (fenoxycarb)	X			X		X	X			IGR + CA	12	7B	Insect growth regulator so only active on immature stages. Treat as late in day as possible and vent before re-entry.
Pylon (chlorfenapyr)			X		X	X				PL	12	13	Has translaminar activity with extended residual activity. Avoid spraying plants in bloom. Also labeled for control of broad and cyclamen mite. Effective against western flower thrips adults and larvae as a foliar spray, and drench applications are effective against fungus gnat larvae in the growing medium.

PESTICIDE	APHIDS	LEAFMINERS	FUNGUSGNATS	WHITEFLIES	MITES	THRIPS	SCALE	CATERPILLARS	MEALYBUGS	CLASS	REI (hr)	IRAC*	COMMENTS
Pyreth-It (pyrethrins plus PBO)	X		X	X			X	X		BO	12	3A + 27A	Contact activity only so thorough coverage of all plant parts is important. Has short residual activity.
Pyrethrum TR (pyrethrins plus PBO)	X		X	X	X		X			BO	12	3A + 27A	Contact activity only so thorough coverage of all plant parts is important. Has short residual activity. Not recommended for use on plants in bloom or poinsettia bracts displaying color. Make applications as late in day as possible and vent before re-entry.
Rycar (pyrifluquinazon)	X			X		X			X	PDZ	12	9B	Has both contact and translaminar properties.
Safari (dinotefuran)	X	X	X	X		X	X		X	NN	12	4A	Systemic insecticide with translaminar properties. Has extended residual activity. Very water-soluble. Can be applied as a spray or drench. Labeled for use against leafminers, aphids, whiteflies and thrips. However, only provides thrips suppression.
Sanmite (pyridaben)				X	X					PD	12	21A	Contact activity only so thorough coverage of plant parts is important. Provides extended residual activity. Labeled for control of broad mite.
Savate (Judo) (spiromesifen)				X	X					TA	12	23	Has translaminar properties. Provides up to 28 days of residual activity. More effective on larvae and nymphs than adults. Not directly harmful to most predatory mites.

PESTICIDE	APHIDS	LEAFMINERS	FUNGUSGNATS	WHITEFLIES	MITES	THRIPS	SCALE	CATERPILLARS	MEALYBUGS	CLASS	REI (hr)	IRAC*	COMMENTS
Scimitar (lambda-cyhalothrin)	X	X		X		X		X		PY	24	3A	Contact activity only so thorough coverage of plant parts is important. Primarily used for control of leafminer adults. May be directly harmful to natural enemies.
Shuttle O (acequinocyl)					X					ND	12	20B	Contact activity only so thorough coverage of all plant parts is important. Do not use in succession with other miticides with similar modes of action. Does not have translaminar activity.
Sirocco (abamectin and bifenazate)	X			X	X	X				ML and CARB	12	6 + 20D	Contains two miticides with different modes of action. Has translaminar properties.
SuffOil-X (mineral oil)	X		X	X	X	X	X		X	OR	4	Unclassi-fied	Contact activity only so thorough coverage of all plant parts is required. Active on most life stages of insect and mite pests. Do not spray when relative humidity is >80%.
Sultan (cyflumetofen)					X					BK	12	25A	Not effective against broad mite, bulb mite, cyclamen mite, flat mite or rust mite. Contact activity only so thorough coverage of plant parts is important.
Talstar (bifenthrin)	X	X	X	X	X	X	X	X	X	PY	12	3A	Contact activity only so thorough coverage of all plant parts is important. Also labeled for control of broad mite. Primarily used for control of leafminer adults.

PESTICIDE	APHIDS	LEAFMINERS	FUNGUSGNATS	WHITEFLIES	MITES	THRIPS	SCALE	CATERPILLARS	MEALYBUGS	CLASS	REI (hr)	IRAC*	COMMENTS
Talus (buprofezin)				X			X		X	IGR	12	16	Insect growth regulator so only active on immature stages. May sterilize adult female whiteflies.
Tame (fenpropathrin)	X			X	X		X	X	X	PY	24	3A	Contact activity only so thorough coverage of all plant parts is important. Can be mixed with acephate (Orthene) to enhance control of thrips.
TetraSan 5 WDG, Beethoven TR (etoxazole)					X					IGR	12	3A	Mite growth regulator with activity on eggs, larvae and nymphs with no activity on adults. Has translaminar properties.
Triact 70 (clarified hydrophobic extract of neem oil)	X			X	X		X			BO	4	Unclassified	Contact activity only so thorough coverage of plant parts is important. Effective against eggs, larvae (nymphs) and adults. Apply early morning or late evening. Has short residual activity. Do not apply to certain plants in bloom including: impatiens, fuschia, hibiscus, ornamental olive trees, and some carnation varieties without prior testing. Cannot be used on roses. Only labeled for use on a limited number of plants.
TriStar 8.5SL (acetamiprid)	X	X		X		X	X		X	NN	12	4A	Systemic insecticide with translaminar properties. Has extended residual activity. Can only be applied as a foliar spray. Not labeled for drench applications.
Ultra-Pure Oil (mineral oil)	X		X	X	X	X	X		X	OR	4	Unclassified	Contact activity only so thorough coverage of all plant parts is important. Active on most life stages of insect and mite pests. Do not spray when the relative humidity is >80%.

Rate or dosage

Most insecticide or miticide labels contain a range of rates that may be used. The low rate is often considered the *preventative rate*, while the high rate is considered the *curative rate*. If the insect or mite pest population is excessive, then the curative rate should be used; however, if the insect or mite population is relatively low the preventative rate may be used.

Application frequency

Application frequency is a very important and often overlooked factor in determining the effectiveness of an insecticide or miticide. Many insecticides and miticides have short residual activity. As such these materials, in general, need to come into direct contact with insect or mite pests to be effective. Most insecticides and miticides are effective on certain life stages (e.g., larva, nymph, and adult). For example, *Bacillus thuringiensis* subsp. *israelensis* (sold as Gnatrol) only kills the larval stage of fungus gnats, whereas the eggs, pupae, and adults are not affected. A second application needs to be applied later as the eggs hatch into larvae. Meanwhile unaffected adults lay additional eggs, which mean another application is warranted in order to control the next generation of larvae. An application of an adulticide will kill fungus gnat adults, thus preventing egg-laying.

Phytotoxicity

Insecticides and miticides can cause plant injury if not used properly; according to label directions. It is important to consider the following prior to making an insecticide or miticide application:

1. Read the pest control material label to determine if there are precautionary statements indicating plant species that should not be treated.
2. Always test spray a small sample of the crop when applying an insecticide or miticide for the first time. Most symptoms will appear within 10 days following application.
3. Not all plant varieties respond the same. There are often specific varieties of a particular species that are more susceptible than others.
4. The higher the insecticide or miticide concentration used, the more potential for problems associated with phytotoxicity. Therefore, do not apply insecticides or miticides at concentrations higher than the recommended labeled rate.
5. Flowers and bracts are generally more sensitive than leaves; therefore, control insect and mite pests prior to plants flowering.
6. The spray solution should be agitated frequently; otherwise, the solution at the bottom of the tank may be at a higher concentration resulting in phytotoxicity.
7. Maintain records of observed phytotoxic symptoms for all plants.
8. Tank mixing two pest control materials may increase the possibility of phytotoxicity.
9. Do not use the same sprayer for herbicides, and insecticides or miticides. Always have a separate sprayer for each general type of pest control material.
10. Avoid making frequent applications of insecticidal soaps and horticultural oils as this may increase the risk of phytotoxicity.

Pest Control Materials Labeled for Use in Greenhouses for Control of Insect and Mite Pests

Abbreviations used in Table 2

CLASS: BO = botanical; CA = carbamate; CARB = carbazate; CBOX = carboxamide;

CH = chlorinated hydrocarbon; IGR = insect growth regulator; ND = napthoquinone derivative;

MI = microbial; ML = macrocyclic lactone; OP = organophosphate; OR = other; OT = organic tin compound; NN = neonicotinoid; PD = pyridazinone; PL = pyrrole; PP = phenyl pyrazole; PDZ = pyridine azomethine; PY = pyrethroid; SO = soap; SP = spinosyn; TA = tetronic acid; TET = tetrazine.

PRECAUTIONARY STATEMENT
To protect people and the environment, pesticides should be used safely. This is everyone's responsibility, especially the user. Read and follow label directions carefully before you buy, mix, apply, store, or dispose of a pesticide. According to laws regulating pesticides, they must be used only as directed by the label.

DISCLAIMER STATEMENT
This publication contains pesticide recommendations that are subject to change at any time. The recommendations in this publication are provided only as a guide. It is always the pesticide applicator's responsibility, by law, to read and follow all current label directions for the specific pesticide being used. The label takes precedence over the recommendations found in this publication. Use of trade or brand names in this publication is for clarity and information; it does not imply approval of the product to the exclusion of others which may be of similar, suitable composition, nor does it guarantee or warrant the standard of the product. The author(s), The University of Tennessee, The Institute of Agriculture and the University of Tennessee Extension assume no liability resulting from the use of these recommendations.

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