

Greenhouse Tomatoes

Pest Management in Mississippi

Greenhouse tomato growers produce vine ripe tomatoes at a time of year when homegrown tomatoes are not available. Many disease and insect pests can attack greenhouse-grown tomatoes and hurt both production and quality. Greenhouse tomato producers must be able to accurately scout for and identify these pests and know how to effectively and economically control them.

Growers who successfully combat greenhouse tomato pests rely on integrated pest management (IPM). IPM simply means that growers use a combination of biological, cultural, and chemical methods to suppress pest populations, rather than relying only on one method, such as repeated insecticide use. This integrated approach uses preventive measures to avoid likely insects and diseases, crop monitoring to allow early detection, biological control when possible, and pesticides when needed. A sound IPM program reduces pesticide use, allows more timely application of needed pesticide treatments, and improves pest control.

Insect Management

Many of the same insect pests that attack field-grown tomatoes also attack greenhouse tomatoes. But because of the enclosed, controlled environment of the greenhouse, insect management is different from what is used in the field. The most important components of insect management in greenhouse tomatoes are discussed below.

Exclusion

Exclusion, keeping insects from entering the greenhouse, is a key part of greenhouse insect management. Many common

pests that attack greenhouse tomatoes are small flying or windborne creatures that can easily be sucked into the greenhouse through ventilation fans and cooling pads or can easily enter through other openings. By building the greenhouse so that it is “bug tight,” growers can avoid many serious insect infestations. Although building an insect-proof greenhouse requires additional planning and expense, it is well worth it.

One of the first steps in building an insect-proof greenhouse is to install proper screening over air intake vents or cooling mats. Because many greenhouse insect pests are so small, it takes very fine screening to exclude them. Thrips are the smallest insect pests that need to be screened out, and a screen mesh of 81x81 is required. Obviously, screening that keeps out thrips also keeps out larger pests, such as aphids and whiteflies.

One very important point to keep in mind when installing screening over intake vents or cooling mats is that such fine mesh screens greatly reduce airflow. So if you install screening, you may need to build special screen-covered enclosures over the vents that support enough screen surface area to provide the necessary air flow. Greenhouse manufacturers and suppliers sell screening of various opening sizes and can provide information and guidance on proper installation to achieve the necessary airflow.

In addition to properly screening air intake points, it is also important to be sure that any other possible entries are sealed. Even in properly screened and sealed greenhouses, insect pests can enter or be sucked into the greenhouse through the door as workers come and go. Adding

an air-lock or enclosed porch over the door is an inexpensive way to prevent this kind of insect entry. Of course, once you have gone to the trouble and expense of screening and sealing a greenhouse, it is important to properly maintain the exclusion devices. Repair holes or tears immediately, and clean screening to maintain airflow.

Sanitation

Sanitation is another major part of greenhouse pest management. Many tomato pests also occur on other crops or broadleaf weeds. For this reason, it is important to avoid growing other crops next to the greenhouse and to prevent heavy growths of broadleaf weeds around the outside edges of the greenhouse. Not letting weeds and volunteer plants grow inside the greenhouse, during either cropping or noncropping periods, is even more important, because such plants can serve as hosts for a number of pests and can let pests survive inside the greenhouse during noncrop periods.

One of the most important points in sanitation is to begin with insect-free transplants and avoid bringing other plants into the greenhouse once you plant the crop. Serious infestations of insects or diseases can be introduced on new plants, either vegetables or ornamentals, that are brought into the greenhouse or exchanged with other growers. It is best to avoid this entirely. If new plants are introduced, quarantine them in another location and closely observe them for several days to be sure they are pest free.

Finally, keep the greenhouse clean and free of debris. Promptly remove pruned leaves as well as cull and over-ripe fruit.

Scouting

Scouting and early detection are critical to successful insect control. Purposefully inspect plants one to two times per week to check for developing insect problems. Do this by walking through the greenhouse, making random stops, and visually examining both upper and lower leaf surfaces as well as buds, blooms, and fruit for insect pests. Give extra attention to plants or areas that show unusual symptoms or appearance. Many insect infestations begin in isolated spots within the greenhouse but quickly spread if not controlled. Because many insects and mites are so small, a 10 to 20X hand lens is an important tool to use when scouting. Also be alert for insect pests when performing routine maintenance procedures, such as pruning, training, or harvesting.

There are a number of pest management tools you can use in addition to visual scouting. Yellow sticky cards from greenhouse supply companies can help detect whiteflies and many other greenhouse pests early. Pheromone traps available for tomato pinworm can allow critical early detection if you use them

according to directions and replace the lure as required.

Cultural Practices

Many cultural practices can help reduce insect populations. Maintaining good weed control and not bringing other plants into the greenhouse were discussed in the "Sanitation" section. Pruning lower leaves after harvesting lower fruit clusters is another helpful measure in horticultural and disease management. This can also aid in insect control by removing large numbers of developing leafminers and whiteflies. But growers practicing biological control need to remember that excessive leaf removal can interfere with biological control efforts by removing parasitized pests before the parasites emerge. Managing irrigation to avoid leaks and excessive moisture aids in control of fungus gnats.

Biological Control

Biological control can be a viable alternative to using insecticides in greenhouse tomato production and works especially well with using bumble bees for pollination. Successful biological control requires careful, frequent scouting, accurate pest identification, knowledge of the pest biology, knowledge and understanding of the biology of the biocontrol agents used, and careful selection and timely release of biocontrol agents. One key to successful biocontrol is to understand that it is not meant to eliminate all insect pests. Low levels of pests must be present to provide food for the biological control agents. It is important to begin releases of biological control agents when pest populations are low to keep them from reaching damaging levels.

Several suppliers specialize in developing and producing predatory and parasitic insects and mites, along with other biological control agents, for use in greenhouses. If you are interested in using this approach, contact suppliers to learn details about which species are available, recommended release rates, specific environmental conditions under which the agent performs best, frequency of release, cost, and other information. Keep in mind that biological control agents are living organisms, and the quality of the agents can differ between sources. Success of biocontrol often depends on careful management of environmental conditions, especially temperature and humidity. Certain species of predators or parasites perform best under certain conditions, and in some cases different strains of the same species are available for different conditions.

One of the major factors affecting success of biological control efforts is insecticide use. For example, you cannot conduct a successful biological control program against whiteflies if broad-spectrum, long-residual insecticides are being used regularly in the green-

house to control other pests. The biological control effort must target all major pests likely to occur in the greenhouse. When insecticide sprays are required, carefully select products compatible with any biological control agents being used. Fortunately, a number of biopesticide and insect growth regulator (IGR) type products meet this requirement.

Insecticides

Insecticides are the last resort in any IPM system. However, insecticide use is often needed to keep pest populations from reaching damaging levels. Few insecticides are specifically labeled for use on greenhouse vegetables, but there are many effective products that do include specific directions for use on greenhouse tomatoes on their labels. Recently the EPA has indicated that insecticides labeled for a specific field-grown crop may also be used on greenhouse crops of the same species, provided that there are no restrictions on the label that specifically prohibit or implicitly preclude use in greenhouses. This increases the number of insecticide options. However, it is best to use products that specify greenhouse use on the label whenever possible. In many cases insecticides labeled primarily for field-grown crops are sold in large-volume packages that are not practical for smaller greenhouses. In the following insecticide recommendations for specific pests, insecticides that are labeled for use on field-grown tomatoes, but are not specifically labeled for the use in greenhouses are listed in brackets {}.

When using any pesticide in greenhouses, read and follow all label instructions. Be sure to wear appropriate protective equipment because pesticide exposure can be greater in enclosed areas. **Using properly fitting respirators is especially important when making pesticide applications in greenhouses.** Also take care to use appropriate rates. Rates for pesticides used in field-grown crops are usually given in amounts per acre, and these must be carefully converted and double-checked for use on smaller greenhouse plantings. Applying pesticides at excessive rates can result in plant injury and other problems.

Major Insect Pests

Aphids

Green peach aphid	<i>Myzus persicae</i>
Potato aphid	<i>Macrosiphum euphorbiae</i>

Several other species

Aphids (plant lice) are small, soft-bodied insects that differ in color from light green or yellow to pink, red, or black. There are several different species, and all of them suck plant juices, causing leaves to curl and turn yellow. Some species inject toxic saliva or disease-causing organisms during feeding. Heavy aphid infestations may cause a failure of bloom set in some veg-

etable crops. Aphids excrete large amounts of sticky undigested plant sap, known as honeydew, which can support the growth of sooty mold fungus. Although sooty mold fungus does not attack the plant directly, heavy amounts of honeydew and sooty mold can discolor fruit and interfere with photosynthesis.

Biology

Most aphid species reproduce without mating and give birth to live aphid nymphs rather than laying eggs. Under the best conditions, the nymphs, which are usually all females, can reach maturity and begin bearing young of their own within 7 days. Because of this high reproductive rate, heavy infestations can develop quickly. Mature females may be winged or wingless depending on environmental conditions. Infestations easily spread through the wind-assisted flight of winged females. Although aphids usually have a fairly narrow host range, many species occur on a number of vegetable plants as well as certain weeds. Outdoors, aphids are preyed on and parasitized by many beneficial insects, and this naturally occurring biological control normally keeps aphid populations in check. Outbreaks occur when aphid populations get ahead of biological control or when biological control is disrupted by insecticide treatments targeted toward other pests.

Management

Exclusion and sanitation are important in avoiding aphid infestations. Proper screening of ventilation fans and keeping greenhouses “bug tight” will prevent entry of windborne females. Do not allow weeds and other plants to grow in the greenhouse during non-crop periods, and maintain control of broadleaf weeds around the outside edges of the greenhouse. Also, do not allow other plants to be brought into the greenhouse when a crop is in production. Aphid infestations often begin in isolated areas within the greenhouse, and prompt spot treatments can eliminate these infestations before they spread. Several biological control agents are available for use against aphids in greenhouses, including generalist predators, such as lacewings and lady beetles, and several species of parasitic wasps.

Insecticides for Aphid Control

Azadirachtin, *Beauvaria bassiana*, imidacloprid, malathion, paraffinic oil, potassium salts of fatty acids, pyrethrins.

Imidacloprid is a systemic insecticide that is effective against aphids. Paraffinic oil, potassium salts of fatty acids and pyrethrins provide contact control but have very short residual activity. The biopesticide *Beauvaria bassiana* is a fungal disease that infects aphids.

Whiteflies

Silverleaf whitefly *Bemesia argentifolii*
Greenhouse whitefly *Trialeurodes vaporariorum*

Whiteflies are the most common and most problematic insect pests of greenhouse tomatoes. Despite their name, whiteflies are not true flies; they are closely related to aphids. Adults are about 1/16 inch long and have four wings covered with a white, powdery material. They rest with their wings folded tent-like over their backs and are weak fliers. Immature whiteflies are very different from adults. Except for the newly hatched crawlers, immatures are immobile scale-like insects. They look like tiny, oval scales attached to the undersides of leaves. Whiteflies cause damage by sucking sap from plants and producing honeydew, which supports the growth of sooty mold. These insects can build up to very high levels in protected greenhouse environments and are capable of causing severe crop loss.

There are several different species of whiteflies, but the two most common species in greenhouse tomatoes are greenhouse whitefly and silverleaf whitefly. Of these, silverleaf whitefly is the bigger threat and is more difficult to control. Silverleaf whiteflies can transmit several significant tomato viral diseases, and they also cause a problem known as irregular ripening. This is thought to be physiologically induced, meaning that it is not caused by disease but is an indirect result of the whitefly infestation.

It is important to know which species of whitefly you are dealing with before implementing treatments. Proper species identification is especially important when using biological control, because many biological control agents only work on a certain species. The parasitic wasp *Encarsia formosa* is especially effective against greenhouse whitefly, but other parasites are more effective against silverleaf whiteflies.

Biology

Female whiteflies lay about 150 eggs, usually attached to the undersides of leaves. In greenhouses, eggs hatch in 4 to 7 days into tiny, white, oval crawlers. These move a short distance, insert their mouthparts into the plant tissue, produce a protective scale-like covering, and do not move for the rest of their nymphal development. Nymphs go through three instars and a pupa stage before reaching adulthood. The winged adults emerge through a slit in the pupal covering. Full development usually takes 25 to 30 days in greenhouses. Adults may live up to 30 days.

Management

Yellow sticky cards placed in the upper plant canopy are useful for monitoring whitefly populations. Exclusion and sanitation are the keys to whitefly management. You can also buy and release certain predators and parasites into the greenhouse system to man-

age whiteflies. But to be effective, biological control must be well planned and begun when whitefly populations are low. It is important to know which species of whitefly you are targeting with biocontrol efforts. For example, *Encarsia formosa* can provide good control of greenhouse whiteflies, but silverleaf whiteflies are more effectively controlled by *Eretmocerus* wasps. There are also some predatory insects, such as the tiny lady beetle *Delphastus pusillus*, that attack whiteflies. Biopesticides, such as *Beauveria bassiana* fungus, are also useful in controlling whiteflies.

Although you need low levels of whiteflies when implementing biological control, good exclusion practices are still important. If other pests are present, you might have to make insecticide applications that would disrupt the biological control program. Properly screened greenhouses also keep expensive biological agents from escaping after their release.

Insecticides for Whitefly Control

Azadirachtin, *Beauveria bassiana*, buprofezin, imidacloprid, paraffinic oil, potassium salts of fatty acids, pyrethrins, pyriproxyfen, spiromesifen.

Effective control of whiteflies depends on controlling the immature stages. Azadirachtin is a botanical insect growth regulator useful against whiteflies. It controls the immatures and has a short preharvest interval (PHI). Buprofezin (Talus) and pyriproxyfen (Distance) are insect growth regulators that are very useful against whiteflies. Imidacloprid and acetamiprid are useful systemic insecticides that control immatures as well as adults. Imidacloprid (as Provado) has a very short PHI when applied as a foliar spray. Imidacloprid (as Admire) may also be applied one time per crop as a media drench, with a 0-day PHI. Paraffinic oil, and potassium salts of fatty acids provide contact control of adults and crawlers. Pyrethrins will provide short-term control of adults, but these products will not control immature whiteflies.

Whiteflies are difficult to control with insecticides because the eggs and nonfeeding pupae are not controlled by either contact or systemic treatments, and the actively feeding nymphs are hard to control with contact insecticides. To control whiteflies with insecticides, it is important to scout regularly and begin control efforts when whiteflies are first detected. There are several insecticides that kill exposed adult whiteflies, but effective control of whiteflies depends on controlling the immature stages. Fortunately, greenhouse growers now have access to several systemic or insect growth regulator products that are effective against whiteflies. The growth regulators buprofezin (Talus) and pyriproxyfen (Distance) and the systemic insecticide imidacloprid (Admire) are especially useful whitefly control tools.

When applying foliar sprays for whiteflies, it is best to spray when the temperature is 70 to 80 °F. Because whiteflies can quickly develop resistance to insecticides they are exposed to repeatedly, pay close attention to information on labels about resistance management guidelines and alternate insecticide use.

Tomato Psyllids *Paratrioza cockerelli*

Tomato psyllids are more common in western regions but have not yet been found in greenhouses in Mississippi. Still, Mississippi growers need to be aware of these pests. Psyllids are relatives of aphids and whiteflies. Adults are only about 1/10 inch long and look like miniature cicadas. They have clear wings that are folded roof-like over the body when the insect is resting. The small nymphs are tan, yellow, or green and roughly oval-shaped and flat. Mature nymphs are a little less than 1/16 inch long. They somewhat resemble immature whiteflies. Psyllid nymphs have distinct red eyes, but immature silverleaf whiteflies also have red eyes at certain points in their development. Nymphs and adults produce large amounts of white, waxy material that builds up in areas where the insects feed. This material is often one of the first indicators of psyllid infestations.

Tomato psyllids also occur on potatoes and other plants and weeds in the nightshade family, known as solanaceous plants. The nymphs inject a toxin into the plant that results in a condition known as “psyllid yellows.” As the name implies, affected plants have a yellowing midrib and leaf margins and upward-curling leaves. Severely affected plants may be stunted and have a faded purple color. Infested plants can suffer from greatly reduced growth and fruit production. It takes only a few nymphs per plant to cause these serious symptoms.

Biology

Female psyllids can lay several hundred eggs which they place on stalks on the undersides of leaves. Eggs hatch in about 4 days, and the resulting nymphs feed on leaves using their sucking mouthparts. Once they begin to feed, the nymphs move very little. The nymphal period lasts about 2 weeks, and a generation can be completed in about 4 weeks. There are several generations per year, and this insect can grow year-round in greenhouses.

Management

The best control method is to prevent the introduction of this pest through sanitation and exclusion. Because of the high level of damage that even low numbers of tomato psyllids can cause, the tolerance level for this pest is quite low. Insecticides can be used to eliminate infestations if they do occur.

Insecticides for Tomato Psyllid Control

Pyrethrins, imidacloprid

This pest is susceptible to contact sprays of pyrethrins, but make two applications at 7-day intervals. The systemic insecticide imidacloprid also controls psyllids. Spinosad is not specifically labeled for psyllids, but it is labeled for tomatoes and has given high levels of control of tomato psyllids in some trials.

Thrips

Western flower thrips *Frankliniella occidentalis*
Tobacco thrips *Frankliniella fusca*
Onion thrips *Thrips tabaci*
Several other species

Thrips are tiny insects, less than 1/16 inch, that feed on plant leaves, blooms, and fruit with “punch and lap” mouthparts. There are several different species of thrips, but western flower thrips, onion thrips, and tobacco thrips are the most common. Although they don’t often occur in greenhouse tomatoes in large enough numbers to cause serious injury, thrips are important pests because they can vector tomato spotted wilt virus (TSWV). Thrips can scar and distort fruit by feeding on young fruit.

Biology

Thrips reproduce on a large number of crops and weeds, many of which serve as hosts of TSWV. The eggs, which are inserted into plant tissue, hatch into elongate, spindle-shaped larvae. They begin feeding on the undersides of leaves by puncturing cells with their ice pick-like mandible and lapping up the resulting plant fluid. The larvae feed in this fashion for 8 to 12 days before moving to the ground, finding a protected location, and entering the pupal stage, which lasts 3 to 7 days. Adult thrips, which have fringed wings, return to host plants to feed in the same manner as the larvae and to deposit eggs. Although they are small and are relatively weak fliers, adult thrips are easily windblown and can migrate long distances. Adult flower thrips often gather in blooms where they feed on pollen. Immature thrips become infected with TSWV when feeding on infected plants. Migrating adults remain infected for the rest of their lives and spread the virus to other hosts.

Management

Because they can vector TSWV, exclusion and sanitation are the best methods of controlling thrips. But because of their small size, you need very fine mesh screening to exclude thrips. Screening and other exclusion practices will also prevent entry of other greenhouse insect pests. Blue or yellow sticky cards are useful monitoring tools. Blue is more attractive to thrips, but yellow cards attract a wider range of pests, including thrips.

Be careful to avoid bringing thrips or TSWV-infested plants into the greenhouse. It is also important to control and prevent the growth of broadleaf weeds around the greenhouse because these weeds can serve as hosts for both thrips and TSWV. When insecticide treatment is needed, contact insecticides such as spinosad or malathion can provide effective control. Other control options such as *Beauveria bassiana* may be more compatible in greenhouses where you use biological control. Several species of predatory mites prey on immature thrips.

Insecticides for Thrips Control

Azadirachtin, *Beauveria bassiana*, chlorfenapyr, malathion, paraffinic oil, potassium salts of fatty acids, pyrethrins, spinosad.

Although spinosad is mainly used to control caterpillar pests, it is also one of the best products for thrips control. Malathion, paraffinic oil, potassium salts of fatty acids and pyrethrins provide contact control of thrips. Azadirachtin is a botanically derived insect growth regulator. *Beauveria bassiana* is a biopesticide mainly used to control whiteflies, but it also provides some control of thrips.

Leafminers

Vegetable leafminer

Liriomyza sativae

Serpentine leafminer

Liriomyza trifolii

Leafminers feed on a variety of weeds and vegetable crops, including tomatoes. In the field, naturally occurring parasites and predators often keep leafminer populations in check. However, leafminers can be significant pests in greenhouses because the naturally occurring parasites and predators are excluded. The leafminers most commonly encountered in greenhouse tomatoes are vegetable leafminers, *Liriomyza sativae*, and serpentine leafminers, *Liriomyza trifolii*. Adults of both species are small flies, about 1/12 inch long, that are black with yellow markings. Their overall appearance is similar to that of fruit flies. Damage is caused by the larvae, which mine in the leaves, causing winding or blotch-shaped mines that reduce leaf area and interfere with translocation within the leaf. These pests never attack the fruit directly. Although light infestations (one to two mines per leaf) have little negative effect, heavy infestations can decrease functional leaf area and overall productivity. However, because heavy infestations are usually found in the lower portion of the plant, yield effects are less than they would be if young leaves were attacked.

Biology

Because leafminers prefer to deposit their eggs in mature leaves, egg laying is concentrated in the middle and lower parts of the plant. The female flies insert their eggs into the leaf tissue individually. A female may lay several hundred eggs during her lifetime. The

eggs hatch in about 3 days, and the small larvae begin feeding between the upper and lower leaf surfaces, creating narrow, winding mines. As larvae grow, the width of the mines increases and mines often become blotch-shaped. Depending on temperature and other environmental conditions, the leaf-mining stage lasts 5 to 12 days. Larvae then emerge from the leaf to form yellowish-orange, oval-shaped pupae, which usually roll off the foliage onto the ground. A new generation is produced about every 23 days, but there is usually great overlap of generations in greenhouse infestations.

Management

Pruning lower leaves is a standard production practice that helps control diseases as well as leafminers. But you need to promptly remove pruned leaves from the greenhouse. Plastic sheets placed over the surface of the growing medium can prevent pupae from falling in the growing media, where survival is higher, and cause them to roll into the aisle where they can be swept or vacuumed. *Diglyphus isaea* and *Dacnusa siberica* are two species of parasitic wasps commonly used for biological control of leafminers.

Insecticides for Leafminer Control

Azadirachtin, pyrethrins, spinosad.

Although spinosad is mainly used to control caterpillar pests, it also has activity against leafminers. Malathion and pyrethrins are used to control adult leafminers.

Because they are protected inside the leaf, larval leafminers can be difficult to control. Leafminers often quickly develop resistance to insecticides after repeated exposure.

Fungus Gnats

Bradysia spp.

Fungus gnats are small, dark, mosquito-like flies that are less than 1/8 inch long and have long, beaded antennae. The adults are relatively harmless. The larvae feed on fungi in the growing medium as well as on roots and root hairs, and heavy infestations of larvae can cause enough root pruning to interfere with nutrient uptake. The larvae are slender and clear with a black head capsule and may be up to 1/5 inch long when fully mature. These pests are most abundant in the winter and spring.

Biology

Adults gather in moist, shady areas where they lay their eggs in strings of 3 to 40 on the surface of the growth medium. Eggs hatch within 3 - 6 days, and larvae begin feeding on fungi, root hairs, and roots. Larvae mature in about 2 weeks, construct a pupal case, and remain there about 3 - 7 days before emerging as adults. Adults live about 1 week, and females can lay more than 100 eggs during this period.

Management

Use yellow sticky traps placed near the growing medium at the base of the plants to monitor for fungus gnats. Practice good water management to avoid accumulations of moisture. Fungus gnats can also be controlled using biological agents, such as the soil-dwelling predatory mite *Hypoaspis miles*, or the insect-infecting nematode *Steinernema feltia*.

Insecticides for Fungus Gnat Control

Azadirachtin, *B.t. israelensis*, imidacloprid, malathion, pyrethrins.

The best way to control fungus gnats is to use media drenches to control the larvae. Treatments containing azadirachtin or *Bt israelensis* can be used as media drenches. Foliar sprays of short-residual insecticides, such as pyrethrins or malathion, can provide short-term reductions of adult numbers, but they will not control larvae and will not be effective as stand-alone treatments.

Spider Mites

Two-spotted spider mite *Tetranychus urticae*

Several other species

Spider mites are not insects but tiny, eight-legged pests that feed on the undersides of leaves. Although spider mites are visible with the naked eye, it takes a 10X or higher power hand lens to really be able to see these pests. Damage is caused by both adults and immatures, which feed on the undersides of the leaves, removing sap and causing the leaves to become discolored. Where populations are heavy, they can cause leaves to drop off. There are several different species of spider mites, ranging from light green to red. Two-spotted mites are probably the most common species and are also one of the most difficult to control.

Spider mites are most likely to reach damaging populations under hot, dry conditions. Initial signs of infestation are leaves that look stippled. Close examination of the undersides of leaves with a hand lens will reveal all stages of mites and eggs. When infestations are heavy, a fine webbing of silk will often be present, and mites may be found on the upper surface of the leaves.

Infestations often begin in isolated spots within the greenhouse, and prompt application of spot treatments will often prevent spread to the remainder of the house. Although they are wingless, mites can easily spread throughout the house on workers performing normal maintenance operations, such as pruning or harvesting. Mites can also be brought into the greenhouse on the clothing of workers or on plants that are brought into the greenhouse.

Biology

Eggs are deposited on the undersides of leaves where they hatch into six-legged immatures known as larvae.

These begin feeding on leaf tissue and soon molt into eight-legged nymphs. The nymphs then develop into sexually mature adults. The rate of development is strongly influenced by temperature and other environmental conditions, but under optimum conditions, two-spotted spider mites can complete a generation in as little as 5 to 7 days. Adult females may live 1 to 2 weeks and deposit up to 100 eggs per female.

Management

Because populations of spider mites can develop on many other species of plants, good sanitation practices are a key to avoiding infestations. Control broadleaf weeds around the outside of the house, and do not let weeds grow inside the house. Several species of predatory mites, such as *Phytoseiulus persimilis*, are available for use in biological control programs.

Miticides for Spider Mite Control

Bifenazate, chlorfenapyr, paraffinic oil, potassium salts of fatty acids, spiromesifen.

Specific miticides, such as spiromesifen, bifenazate or chlorfenapyr, usually give best control.

Tomato Russet Mites *Aculops lycopersici*

Tomato russet mites are much smaller than spider mites and can only be seen easily under a microscope or through a strong hand lens. Adults are about 0.2 mm long and are yellow, cigar-shaped creatures with two pairs of legs located near the larger, head end. These mites belong to the family known as eriophyidae and differ greatly from spider mites, which belong to the family tetranychidae. Because these mites are so difficult to see with the unaided eye, the damage they cause is often mistaken for disease or nutritional deficiency. As their name implies, injury symptoms are leaf and stem russetting or bronzing and leaf curling. The leaf curling is due to the large numbers of tiny mites feeding on the leaves. This pest attacks field-grown tomatoes in the southern areas of the country where warm conditions allow continuous survival of favorable hosts. However, tomato russet mites can survive and reproduce throughout the country in greenhouse-grown tomatoes.

Biology

Tomato russet mites are wingless, but they spread by wind and are carried on clothing, birds, or insects. They have a narrow range of host plants, but they also occur on other solanaceous crops, such as eggplant and pepper, as well as on solanaceous weeds, such as nightshades and jimson weed. Eggs are deposited on the surfaces of leaves and stems, where they hatch into tiny nymphs that immediately begin feeding and quickly grow to adults. They can complete a generation in as little as 7 days.

Management

Sanitation is the key to avoiding infestations of tomato russet mites. Do not allow weeds or volunteer plants to grow in greenhouses between crops because these can serve as hosts. Likewise, maintain good control of weeds, especially solanaceous weeds, in the outside area around the greenhouse, and do not allow potential host plants to be brought into the greenhouse when a crop is being grown.

Miticides for Tomato Russet Mite Control

chlorfenapyr

Sulfur is one of the products traditionally recommended for chemical control of tomato russet mites, but more specific miticides, such as chlorfenapyr, provide better control.

Tomato Pinworms *Keiferia lycopersicella*

These insects are important pests of field-grown tomatoes in subtropical growing areas, but they can potentially occur in greenhouse tomatoes throughout the country. Pinworms are tiny caterpillars that are only 1/4 inch long when fully grown. Despite their small size, these caterpillar pests can cause serious fruit injury. The caterpillars are yellow, gray, or green with purple spots and a brown head. Adults are small, gray moths that are about 1/3 inch long and generally are active at dusk.

Biology

The tiny eggs are usually deposited on the leaves in small clusters. Upon hatching, the tiny larvae bore into the leaf and feed as leafminers, causing white, blotchy mines. After they grow too large to live within the leaf, the larvae fold a leaf or web two leaves together to create a protected environment where they continue feeding. Older larvae also feed by boring into the stem end of developing fruit, causing small, pinhole-like wounds, and this direct fruit injury can cause serious fruit loss unless infestations are quickly found and controlled. Mature larvae exit the infested fruit or leaf folds and usually drop to the ground to pupate.

The life cycle from egg to adult varies but averages about 30 days in the summer and 40 to 55 days in the winter. Tomato is the preferred host, but this caterpillar also attacks eggplant and potato, as well as some solanaceous weeds.

Management

Use pheromone traps to monitor for the presence of pinworm infestations. Proper use of traps provides early detection. Sanitation and exclusion are also important components of pinworm management. Be sure to keep the greenhouse free of volunteer host plants, including solanaceous weeds, during nongrowing periods, and use screening to help exclude moths. Avoid introducing infested plants into the greenhouse,

and promptly remove and destroy infested leaves and cull fruit. Hand removal of infested leaves can be especially helpful in slowing the growth of very low infestations. Moths are attracted to light traps, and light traps can be useful control tools when populations are low. Mating disruption through the use of slow-release pheromone dispensers or microencapsulated pheromone sprays is a useful, noninsecticidal method for controlling pinworms.

Insecticides for Tomato Pinworms Control

Spinosad, chlorfenapyr

Specific caterpillar insecticides, such as spinosad or chlorfenapyr, provide best control when treatment is necessary, but repeated applications will usually be needed to control an established infestation. Because of their protected feeding environment, Bt products are usually not used against pinworms.

Large Caterpillars

Tomato fruitworm

Helicoverpa zea

Armyworms

Spodoptera spp.

Cabbage looper

Trichoplusia ni

There are several species of large caterpillars (over 1 inch long when fully grown) that sometimes infest greenhouse tomatoes. These infestations are most likely during the fall after large numbers of moths have developed on field crops. Because a single female can lay several hundred to over 1,000 eggs, it only takes a few female moths getting into the greenhouse to cause a serious infestation.

Common Species of Large Caterpillars

Tomato fruitworms: Tomato fruitworms are one of the most significant insect pests of field-grown tomatoes. They are less common in greenhouses, but when infestations do occur, they can cause serious losses. This is because, as their name implies, this caterpillar feeds directly on the fruit. This insect attacks many other crops and is also known as the cotton bollworm, corn earworm, or soybean podworm. These are stout-bodied, green or brown striped caterpillars about 1 1/2 inches long when fully grown. The moths are buff brown with a small brown spot on each forewing.

Tomato fruitworms feed on blooms, as well as immature and ripe fruit. The individually laid eggs are most often deposited on leaves near upper bloom clusters. If not controlled, heavy infestations of these caterpillars can destroy more than half a crop. Because large larvae that have already bored into fruit are very difficult to control, it is important to detect infestations and begin treatment when caterpillars are small (less than 1/4 inch long). Tobacco budworm is a similar species that also attacks tomatoes.

Armyworms: Several different species of armyworms occur in greenhouse tomatoes. Fall armyworms vary from light tan or green to nearly black. They have

a distinct inverted white Y-shape on the front of their heads. Their bodies have a greasy appearance and may be up to 2 inches long. Beet armyworm, yellow-striped armyworm, and southern armyworm are some of the other species that are sometimes found on greenhouse tomatoes. All species of armyworms are mainly foliage feeders, but will occasionally damage fruit. Because armyworms lay their eggs in large masses, heavy infestations may occur in isolated areas within the greenhouse, and timely spot treatments can often provide effective control.

Cabbage Loopers: Loopers are pale-green caterpillars with only two pairs of abdominal prolegs (armyworms and tomato fruitworms have four pairs). This causes them to move in a “humpbacked” or looping fashion. They have light stripes down their backs and are up to 1 inch long. Cabbage loopers are leaf feeders and rarely attack fruit, but they are one of the more difficult caterpillars to control. Cabbage looper moths are gray with a silver figure eight or octopus-shaped mark on each forewing.

Biology

Eggs are deposited by female moths that have made their way into the greenhouse. Tomato fruitworm and looper moths lay their eggs individually, but armyworm moths lay their eggs in large masses. Eggs hatch within 3 to 7 days, depending on species and temperature. The small caterpillars begin feeding on leaf tissue. The caterpillar stage lasts about 11 to 17 days with larvae eating more and causing proportionally more damage as they become larger. Caterpillars eat about 80 percent of their total food consumption during the final three days of their larval period. This is why serious injury often appears to occur overnight. Upon completion of its larval development the caterpillar forms a pupa on the foliage or in the soil, depending on species. Moths may emerge from these pupae in as little as 8 to 11 days. However, some species overwinter as pupae.

Management

Because of their size, the moths that produce these caterpillars are easy to exclude from greenhouses (even regular window screening is sufficient), and serious infestations are rare in houses with good exclusion practices. Because large caterpillar pests don’t often invade the greenhouse, biological controls are rarely used on them.

Insecticides for Large Caterpillar Control

B.t. kurstaki, chlorfenapyr, spinosad

Specific caterpillar treatments, such as spinosad, provide good control when applied in a timely and appropriate manner. Chlorfenapyr will control leaf-feeding caterpillars but is less effective against tomato fruitworms. Foliar-applied Bt sprays are most compatible with biological control programs, but because they are slow-acting, these must be applied when caterpillars are small.

Slugs

Several species

Slugs are soft-bodied, gray or mottled, slimy creatures measuring up to 4 inches long. They are unrelated to insects, and their bodies are covered by a thick, slimy mucous. They can occasionally become serious pests in greenhouses. Slugs feed on molds, decaying organic matter, and the foliage of plants. They must have a moist environment, and they prefer darkness. Ideal habitats include under boards, trash, and other debris and in crevices. Slugs are active at night and leave a shiny, slime trail. These trails can be seen on foundation walls, floors, walkways, and plant leaves.

Management

Slugs are best controlled by eliminating their hiding places. This involves removing boards and other debris left on the ground and maintaining good weed control. Heavy growths of weeds can provide good hiding places for slugs, whether inside the greenhouse or around the outside of the house.

Molluscides for Slug and Snail Control

Iron phosphate, metaldehyde.

Slugs can be controlled with specially formulated bait treatments containing iron phosphate or metaldehyde. Because these are pellets or are granular products that are not applied directly to the plants, these treatments are compatible with biological control programs. Metaldehyde is poisonous to pets and wildlife, so be sure to follow label directions.

Insecticides, Miticides, and Molluscicides for Greenhouse Tomatoes

Active Ingredient and Concentration	Trade Name (Supplier)	Use Rate	Pests Controlled	REI (hours)	PHI (days)	Remarks
Azadirachtin 3% EC	Azadir XL (Olympic Hort.)	10 – 16 fl oz/100 gal	Whiteflies, aphids, leaf miners, thrips, caterpillars, fungus gnats	4	0	A botanically based product that acts as an insect growth regulator. Applied as a foliar spray to pests on leaves. Applied as a soil drench for fungus gnat control.
Azadirachtin 3% EC	Azadir XL Plus (certis)	10 – 16 fl oz/100 gal	Whiteflies, aphids, leaf miners, thrips, caterpillars, fungus gnats	4	0	A botanically based product that acts as an insect growth regulator. Applied as a foliar spray to pests on leaves. Applied as a soil drench for fungus gnat control.
Azadirachtin 1.2% EC	Azadirol EC (Gordon's)	2 – 4 tbsp/gal	Whiteflies, aphids, leaf miners, thrips, caterpillars, fungus gnats	4	0	Organic Materials Review Institute (OMRI) approved. A botanically based product that acts as an insect growth regulator. Applied as a foliar spray to pests on leaves. Applied as a soil drench for fungus gnat control.
<i>Bacillus thuringiensis</i> aizawa, 5.4% DF	Xentari (Certis)	1 – 1.5 lb/100 gal	Caterpillars	4	NA	OMRI approved. Only controls caterpillar pests. Apply when larvae are small. This Bt will not control fungus gnats.
<i>Bacillus thuringiensis</i> israelensis, 0.6% liquid	Gnatrol (Valent)	32 – 128 fl oz/100 gal	Fungus gnats	4	NA	OMRI approved. Apply as a soil drench to control fungus gnat larvae. May be applied through irrigation water. This Bt only controls fly larvae and will not control caterpillar pests.
<i>Bacillus thuringiensis</i> kurstaki, 5.4% DF	Dipel DF (Valent)	1 – 2 lb/acre	Caterpillars	4	0	OMRI approved. Only controls caterpillar pests. Apply when larvae are small. This Bt will not control fungus gnats.
<i>Bacillus thuringiensis</i> kurstaki, 40% WDG	Crymax	1.5 lb/100 gal	Caterpillars	4	0	Only controls caterpillar pests. Apply when larvae are small. This Bt will not control fungus gnats.
<i>Beauveria bassiana</i> Strain G11A, 10.9% liquid	Mycotrol O (Emerald Bio-Ag)	1 – 2 qt/100 gal	Whiteflies, aphids, thrips, psyllids	4	0	OMRI approved. A slow-acting biopesticide, apply at 5- to 10-day intervals. This is a fungal disease mainly used to control whiteflies, but it will also infect other listed pests.
Bifenxate, 22.6% SC	Floramite SC (Crompton)	4 – 8 fl oz/100 gal	Spider mites	12	3	Use only on varieties with mature fruit diameter greater than 1 inch. Rotate use with other miticides. Do not exceed two applications per year.
Buprofezin, 40 SC	Talus (SePro)	9-13.6 fl oz/acre	whiteflies, mealybugs, leafhoppers	12	1	This is an insect growth regulator-type product that only controls whiteflies and a few other sucking pests. Do not exceed two applications per crop.
Chlorfenapyr, 25C	Pylon (Olympic Hort.)	6.5 – 13 fl. oz/acre	Spider mites, tomato russet mites, caterpillar pests, thrips, tomato pinworm	12 hours	0	Chlorfenapyr is a miticide that moves from the top side of the leaf to the bottom. It also controls thrips, leaf-feeding caterpillars, and tomato pinworms. Do not use on tomato varieties with mature fruit diameter less than 1 inch. Allow at least 5 to 7 days between applications. Do not exceed two consecutive applications. Do not apply more than three applications per crop.

Insecticides, Miticides, and Molluscides for Greenhouse Tomatoes

Imidacloprid	Admire 2F* (Bayer CropScience)	1.4 fl. oz/1000 plants	Aphids and whiteflies	12	0	Apply in a minimum of 16 gallons of water as a soil drench or through irrigation according to label. Do not make more than one application per year. Do not apply to plants growing in rock wool, perlite, or other soil-less growing media, or plants growing hydroponically. This is a neonicotinoid-type product. Imidacloprid will control leaf-feeding thrips but will not control thrips in blooms. Soil-applied treatments of imidacloprid have long-term adverse effects on bumblebees.
Iron phosphate 1%	Sluggo (Monterey)	1 lb/1000 ft ²	Slugs	NA	NA	OMRI approved. Do not apply directly to plants.
Malathion 79.5%	Malathion 8 Flowable (Gowan)	1.5 - 2 pt/acre	Aphids, armyworms, fruitflies, leaf miners, thrips	12	1	This is an organophosphate insecticide. Malathion provides broad-spectrum control, but many pests have developed resistance.
Metaldelhyde 2%	Ortho Bug-Geta Snail & Slug Killer (Ortho)	1 lb/2000 ft ²	Slugs	NA	0	Do not apply directly to plants.
Metaldelhyde 0.13 bait	No Escape Slug & Snail Killer (Bonide)	1 lb/1000 ft ²	Slugs	NA	NA	Do not apply directly to plants.
Paraffinic oil 98.8%	Ultra-Fine Oil (Whitmire Micro-Gen)	1 - 2 gal/100 gal	Aphids, mites, thrips, whiteflies	4	NA	Do not exceed four applications per season. Provides control by suffocating pests. Spray must contact the pest directly. Oils can cause serious plant injury when used improperly. Read label carefully.
Potassium salts of fatty acids 49.52% liquid	Insecticidal Soap 49.52 (Olympic Hort.)	1 - 2 gal/100 gal	Aphids, spider mites, whiteflies, thrips, psyllids	12	0	You will usually need repeated applications to achieve effective control, but do not exceed three applications within a 2-week period. Spray must contact the pest directly. Insecticidal soaps can cause plant injury when used improperly. Read label carefully.
Potassium salts of fatty acids 49% liquid	M-Pede	1 - 2 gal/100 gal	Aphids, spider mites, whiteflies, thrips, psyllids	12	0	OMRI approved. You will usually need repeated applications to achieve effective control, but do not exceed three applications within a 2-week period. Spray must contact the pest directly. Insecticidal soaps can cause plant injury when used improperly. Read label carefully.

Insecticides, Miticides, and Molluscides for Greenhouse Tomatoes

Pyrethrins 1.4% liquid	Pyganic (King)	16 – 32 fl oz/50 gal	Aphids, thrips, fruit flies, whiteflies, psyllids, fungus gnats	12	0	OMRI approved. Botanical insecticide for fast knockdown of adult insects.
Pyrethrins, 4% + 16% PBO, TR aerosol	Pyrethrum TR (Whitefire Micro-Gen)	One 6-ounce can per 4,500 – 9,000 sq ft	Fungus gnats, aphids, whiteflies, psyllids	12	NA	Total Release Aerosol Fogger for knockdown of adult insects. Available in 2-oz, 6-oz, and 16-oz sizes. Although pyrethrins are botanical insecticides, PBO is an inorganic synergist, and mixtures of pyrethrins and PBO are not approved for organic production.
Pyrethrins 6% + PBO 60%	Pyreth-It (Whitefire Micro-Gen)	2 – 16 fl oz/acre	Aphids, thrips, fruit flies, whiteflies, psyllids, fungus gnats	12	0	Botanical insecticide for fast knockdown of flying adult insects. Although pyrethrins are botanical insecticides, PBO is an inorganic synergist, and mixtures of pyrethrins and PBO are not approved for organic production.
Pyrethrins 6% + PBO 60%	Pyrethone Crop Spray (Bayer Environmental Science)	12 – 24 oz/100 gal	Aphids, thrips, fruit flies, whiteflies, psyllids, fungus gnats	12	0	Botanical insecticide for fast knockdown of adult insects. Although pyrethrins are botanical insecticides, PBO is an inorganic synergist, and mixtures of pyrethrins and PBO are not approved for organic production.
Pyrethrins 0.6% + Rotenone 0.5%	Pyrellin EC (Webb Wright Corp)	1.5 – 2 pt/acre	Whiteflies, thrips, leaf miners, aphids	12	12 hours	Botanical insecticide. Apply as needed to maintain control.
Pyriproxyfen 11.23% EC	Distance (Valent)	6 fl oz/100 gal	Whiteflies (immatures only)	12	1	This is an insect growth regulator-type product that is especially useful against whiteflies. It does not control adult whiteflies, but interferes with development of immature whiteflies. Must be applied as a foliar spray to control whiteflies. Use only on varieties with mature fruit diameter greater than 1 inch. Do not apply more often than every 14 days. Do not exceed two applications per season.
Spinosad 11.6% liquid	Conserve (Dow Agrosciences)	6 – 10 fl oz/100 gal	Thrips, leaf miners, caterpillars, tomato pinworms	4	1	Do not exceed six applications per crop.
Spiromesifen	Forbid 240 SC (Bayer Environmental Science)	30 – 50 mL/100 L (3.8 – 6.4 fl oz/100 gal)	Spider mites, whiteflies	12	3	Spiromesifen will move through leaves from top to bottom. It provides good control of whiteflies and spider mites. To reduce the potential for resistance, avoid using more than twice per crop.
Sulfur, 90% SP	Microfine Sulfur (Tiger-Sumbelt Ind.)	2 – 5 lb/acre	Tomato russet mites	24	NA	OMRI approved. Do not mix with oil or apply within 2 weeks of an oil spray.

There are 43,560 square feet in one acre, or about 44,000 square feet. You can convert amount per acre to amount per 1,000 square feet by dividing by 44. For example, 10 fluid ounces per acre = 10 divided by 44, or 0.23 fluid ounces per 1,000 square feet.

When measuring small amounts of liquid, it is easier to measure in milliliters rather than fluid ounces. There are about 29.6 milliliters in one fluid ounce. Thus 0.23 fluid ounces per 1,000 square feet = 0.23 multiplied by 29.6, or 6.8 milliliters per 1,000 square feet. There are about 5 milliliters per teaspoon.

When measuring small amounts of dry products, it is easier to measure in grams, rather than ounces. Small digital scales that will accurately measure grams and fractions of grams can be purchased for less than \$100. There are 28.35 grams in one ounce.

Thus 0.38 pounds per acre = 0.38 multiplied by 16 ounces per acre, or 6.08 ounces per acre. 6.08 multiplied by 28.35 = 172 divided by 44 = 3.9 grams per 1,000 square feet.

Disease Identification and Management

To develop a greenhouse tomato disease management program, you must know the diseases that affect the crop and the conditions that can cause problems.

Greenhouse tomato diseases show their symptoms on roots, stems, leaves, and fruit. While some symptoms are common to several diseases, it is usually possible to identify the more common fungal and bacterial disorders by their symptoms. However, some virus diseases may be more difficult to identify. If you have trouble identifying a disease, bring specimens to your county Extension office, or mail them to a plant disease diagnostic lab. Before sending a sample for analysis, check with your county Extension agent about the correct method of sample collection and packaging. Include helpful information, such as recent applications of pesticides, periods of extreme humidity, and other details that could be useful for an accurate diagnosis.

Looking for one key symptom helps most growers identify the disease that has infected the crop. Do not try to remember all symptoms that could be produced by a given disease. Scout plants for those diagnostic features characteristic for a given disease; this improves the accuracy of disease determinations and management steps necessary for its control. Key symptoms described for each of the following diseases will help identify diseases that could occur in the crop.

Disease Identification

Fungus Diseases

Botrytis gray mold (*Botrytis cinerea*) is probably the most common and troublesome disease in greenhouse tomatoes since resistant varieties are not available and the fungus is present in all greenhouses. Infection by the gray mold fungus occurs when the relative humidity is 90 percent or higher. All plant parts can be invaded. Plants are generally more vulnerable during fruit bearing.

Key symptom: Look for light-tan or gray spots on infected leaves. These areas become covered by a brown or gray fuzzy mass of fungus growth, and the leaf collapses and withers. Other sites of infection include dying flowers and the calyx area of fruit. From the calyx, infection proceeds into fruit which quickly becomes water-soaked and soft. Under a hand lens you can see spore-bearing structures that look like bunches of grapes on the infected tissue. Since the causal fungus does not actively attack healthy tissue, stem invasion occurs through branch stubs resulting from pruning or other injured sites along the stem. The tan cankers that form along the stem may be large and often cause early plant death. Under humid conditions, distinct masses of fungus growth form on canker surfaces.

Leaf mold (*Fulvia fulva*) was a common and severe problem in the early 1970s because resistant varieties

were not available. Today, most modern varieties have complete resistance (C5) to all races of the leaf mold fungus (refer to the "Disease Management" section in this publication). Varieties with incomplete resistance (C2) are often affected by leaf mold under humid conditions. Scout these varieties frequently for early symptoms of this disease. Infection by the leaf mold fungus occurs when relative humidity remains at 90 percent or higher for several hours. This disease is favored by the same conditions that encourage gray mold development. Leaf mold symptoms begin on lower, older leaves but progress to younger foliage over time.

Key symptom: Look for pale-green or yellowish areas with irregular margins on upper leaf surfaces. Beneath the yellow spots, areas of olive green velvet growth are visible. Infected leaves become yellow-brown and drop prematurely. Defoliation progresses up the plant.

Early blight (*Alternaria solani*) sometimes causes problems in greenhouse tomatoes. Symptoms appear on leaves, stems, and fruit.

Key symptom: Look for characteristic circular brown leaf spots, up to 2 inches in diameter. Spots contain dark rings with a common center, giving a target-board appearance.

Powdery mildew (*Erysiphe* sp.) is not a widespread greenhouse tomato problem in Mississippi, but it is a fungus disease that is becoming more common.

Key symptom: Powdery mildew is identified by white patches of fine, powdery growth on the upper sides of leaflets. Patches are up to 2 inches in diameter and generally appear on the oldest foliage. Severe cases weaken the plants and lead to lower yields.

Target spot, another fungus disease (*Corynespora cassiicola*), has recently become widespread in greenhouse tomatoes across the state. Early symptoms of target spot first appear on foliage.

Key symptom: Look for small, water-soaked spots on the upper surface of older leaves. The spots rapidly grow to form light- to dark-brown circular lesions with a common center. The rings resemble the target-spot symptoms associated with early blight. Lesions also form on leaf petioles and stems.

Large numbers of target-spot spores occur on infected leaves and stems, and some of these are deposited onto surfaces of young fruit that become infected during humid conditions. Within several days, fruit symptoms appear as sunken, pinpoint-sized, brown lesions. These enlarge and develop into crater-like spots that continue to grow and will crack open as fruit ripens. Growers need to be aware of target spot because this disease may quickly move from foliage to fruit, causing a large reduction in the yield of marketable fruit.

Pythium root rot (*Pythium* spp.) is becoming an increasingly severe problem in Mississippi greenhouses. The species of this fungus that cause problems in the crop are easily introduced into the greenhouse environment via soil clinging to shoes, tools, and, often, contaminated water supplies. A common source that causes Pythium is a nonsterile growth medium (such as river sand piled on bare ground) where it becomes contaminated from underlying soil under wet conditions. Pythium root rot shows up most often when too much water accumulates around roots. Pythium is a water mold fungus and is most aggressive when the growth medium used is too heavy, and bags or other containers don't drain well. When this occurs, the fungus attacks juvenile roots and eventually the main root mass.

Key symptom: Look for large areas of chocolate brown or black roots on wilted, stunted plants with yellow, weak foliage. Infected plants generally do not die and often produce new roots if you correct moisture problems. Send intact root systems from suspect plants to a plant disease clinic for examination if symptoms are not clear.

Fusarium crown and root rot (*Fusarium oxysporum f.sp. radicis-lycopersici*) was first found in Mississippi greenhouse tomatoes in the late 1980s. This disease is almost impossible to control without the use of resistant varieties. Growers in greenhouses where this has been detected need to learn symptoms of the disease and practice proper variety selection.

The FCRR fungus, after initially infecting secondary roots, moves into larger roots and eventually invades the plant's vascular system. Symptoms of FCRR include stunted growth and wilting on sunny days, especially if plants have heavy fruit loads. Infected plants may die after repeated wilting. To diagnose whether a plant has FCRR or Pythium root rot, cut the base of the stem lengthwise.

Key symptom: Look for dark to reddish-brown discoloration of the vascular tissues. Discoloration is evident up 12 to 18 inches above the soil line, in contrast to Fusarium wilt, where discoloration may extend 3 to 4 feet high.

Timber Rot or White Mold (*Sclerotinia sclerotiorum*) is a fungal disease that is being seen more frequently in Mississippi greenhouse tomatoes. Lesions on the lower portion of the stem can result in rapid plant death.

Key symptom: Initially look for a water-soaked lesion forming on the stem of the plant, usually close to the floor and within 2-3 feet of where the stem goes into the growing medium. A white fungal growth may be seen on the stem. The white color of the fungal mycelium is what distinguishes timber rot from gray mold. Plants turn yellow on top, wilt, and die quickly following infection. If you cut through the lesion on the stem, you will likely find hard, black rock-like structures inside. These rock-like structures, called

“sclerotia,” fall to the floor and serve as a source for infection in the next season's crop.

Bacterial Diseases

Plants affected by **bacterial wilt** (*Pseudomonas solanacearum*) rapidly wilt and die without yellowing or showing leaf necrosis. When a wilted plant is cut near the soil line, the inside of the stem looks dark and water-soaked. However, these symptoms are not always easy to detect.

Key symptom: Examine a cross-section of the lower stem for sap to squeeze out when the stem is pressed. In late stages, the stem may become hollow. Test suspicious plants for bacterial wilt. The method is simple, and you can get results in 2 to 5 minutes.

Follow these steps:

- Cut a 2-inch-long section from the base of the stem.
- Fill a small, clean glass container with tap water.
- Suspend the stem (using a wire hanger or other object) about 2 inches into the water.

Key symptom: Look for a thin, milky stream of bacterial cells to appear about 2 to 5 minutes after putting the stem in the water. You see the streaming best when the container is at eye level, with the light coming in from behind.

Pith necrosis (*Pseudomonas corrugata*) is sometimes referred to as bacterial hollow stem. Affected plants sometimes wilt and show a slight yellowing of lower foliage.

Key symptom: On lower stems, look for brown, sunken, necrotic (dead) stem cankers. Lengthwise cuts through cankers reveal hollow stems, a symptom of the disease.

Virus Diseases

Tomato mosaic virus (ToMV) was an important disease until the introduction of resistant varieties in the early 1980s. Today, most modern varieties are resistant to ToMV, a strain of Tobacco Mosaic Virus (TMV), and this disease is no longer a major threat to production. However, growers who use vulnerable varieties need to become familiar with ToMV in case the disease shows up and plant removal becomes necessary.

ToMV diagnosis may be difficult. Symptoms depend on variety, age of plant at time of infection, and environmental conditions. Plants become stunted, leaves may have mild to severe yellow-green spots, crinkles, ridges, strings, or curls. Stems may develop streaks of dead plant tissue. Generally, fruit shows no symptoms, although severe strains may cause internal browning, pitting, or severe mottling.

Because of the wide array of possible symptoms, there are no key symptoms to look for. Because ToMV spreads so easily through pruning, fruit harvesting, and other routine activities, when you suspect the disease you need to get an accurate diagnosis. Send specimens to a disease clinic for testing or microscopic

examination for the presence of virus-inclusion bodies. Remove diseased plants promptly.

Tomato spotted wilt virus (TSWV) can be a widespread problem in greenhouse tomatoes. Like ToMV, diagnosis of TSWV in greenhouse tomatoes can be difficult. Symptoms can be many and varied. TSWV symptoms can be confused with those caused by other viral, fungal or bacterial pathogens, or nutritional disorders. One of the chief vectors of the virus, the Western flower thrips (several other thrips species are also known to transmit the virus), is widespread across the Midsouth. Scouting for and controlling thrips populations is important to prevent the spread of TSWV. Many weedy plants can harbor the virus, so keep a weed-free perimeter around the greenhouse. Test kits are available to check for the presence of TSWV in tomato. The immunostrip test kits are inexpensive, dependable, and easy to use. Contact your county Extension office to find out where to buy test kits.

Key symptom (or at least suspect TSWV): Look for small, dark-brown leaf spots in the upper portion of the plant, which may be arranged in a "ringspot" pattern, dark streaking in petioles and stems, stunted growth terminals, and brown or black lesions on distorted fruit. Submit samples of suspicious plants to your Extension plant disease diagnostic lab. Remove suspect plants.

Tomato Yellow Leaf Curl Virus (TYLCV) was first observed in Mississippi in greenhouse tomatoes in 2001. This destructive virus disease is transmitted by whiteflies. Once infection occurs, the virus prevents further plant development. No flowers or fruit are produced from that point on resulting in a total crop loss.

Key symptom: Symptoms begin showing up about 10-12 days after feeding of whiteflies that carry the virus. Leaves in the top of the plant will develop interveinal chlorosis (yellowing between the veins), and the sides of the leaves will curl upward. The leaves may look crinkled. The symptoms will be subtle at first, but yellowing will increase over time and become very noticeable. Scouting for and controlling whiteflies are important methods of preventing further spread of the virus. Commonly grown Mississippi greenhouse tomato varieties do not have resistance to this disease.

Miscellaneous Diseases

Depending on your location, other diseases could present problems to your crop. For example, *Cercospora* leaf spot, bacterial spot, speck, and canker are detected in greenhouse tomatoes from time to

time. Ask your Extension agent for help in diagnosing diseases that do not fit the "key symptom" approach.

Disease Management

Diseases caused by fungi, bacteria, and viruses can quickly destroy a crop of greenhouse tomatoes when conditions are favorable. However, if you use a combination of recommended practices (IPM), you can manage diseases. Biological, cultural, sanitary, and chemical techniques are necessary, since no single practice controls all diseases affecting the crop.

Biological Management

Biological management is the most economic and effective method of handling several significant diseases. Biological disease management mainly involves using varieties with disease resistance. Compared to the 1970s when the commonly grown varieties did not have disease resistance, most modern greenhouse tomato varieties are resistant to one or more diseases that used to be limiting factors in production.

Cultural Management

Cultural management refers to practices connected to the production of the crop. This method creates conditions that do not favor disease development.

Regulating greenhouse relative humidity is critical since moisture is the main factor influencing plant infection by the fungi responsible for gray mold, timber rot, and leaf mold. Relative humidity must be above 90 percent for spore germination and infection to occur. Most bacterial diseases also need high, relative humidity.

Control of relative humidity is particularly important when greenhouses are tightly sealed to conserve energy. During warm fall and spring days, the air inside the greenhouse picks up moisture, since warm air holds more moisture than cool air. As the air cools in the evening, the moisture-holding capacity drops until the house reaches the dew point and moisture begins to collect on surfaces. Eliminate moisture condensation by three methods:

Keep the ventilators open 1 inch or so (or exhaust fans on low capacity) when the heat comes on in the late afternoon. Cold air enters the

Variety		Disease resistance	
Caruso	Tomato Mosaic Virus (ToMV)	C5 (Leaf mold Races A, B, C, D, and E)	
Capello	ToMV	C5	
Dombello	ToMV	C5	
Perfecto	ToMV	C5	
Laura	ToMV	C2 (Leaf Mold Races A and B)	
Dombito	ToMV	C2	
Jumbo	ToMV	C2	
Match	ToMV	C5	Fusarium crown and root rot (FCRR)
Switch	ToMV	C5	FCRR
Trust	ToMV	C5	FCRR
Blitz	ToMV	C5	FCRR

house while warm, moist air leaves. The cold, drier air entering is heated or further dried. Then, after 5 to 10 minutes, the ventilators are closed or fans turned off. Warm, dry air now exists in the greenhouse.

Moving air in the greenhouse helps reduce moisture on plant surfaces. The horizontal airflow system or the overhead polyethylene ventilation tube system keeps temperatures steady and decreases cold spots where condensation is likely.

When a greenhouse is very moist, you may need to exchange the air one or more times during the night. Greenhouse supply companies sell controls that turn on the fans at programmed times during the night.

Temperature control is also important. For example, greenhouse temperatures no lower than 70 degrees limit development of gray mold. FCRR and Pythium root rot thrive in cooler temperatures as well.

Pith necrosis appears to be most severe when plants are overfertilized with nitrogen. It is likely that Pythium root rot could be more of a problem if roots are injured by high soluble salt levels.

Pruning methods may make stems more vulnerable to gray mold infection since fewer stem lesions develop when you cut or break petioles close to the stem than when you remove them 1 or 2 inches from the stem.

Sanitation Management

Most growers view sanitation as an important part of effective disease management. Unfortunately, not all growers carry out a strict sanitation routine.

Before beginning a new crop:

Rid the greenhouse of debris that could spread a disease in the future from fungi, bacteria, or viruses.

If diseases were a problem in the previous crop, think twice about reusing old growth containers. Do not reuse growth containers (such as rockwool slabs and poly bags) or growth medium from which diseased plants were removed. For a Nutrient Film Technique (NFT) system or modified NFT system, use bleach or another suitable disinfectant before new crop installation.

Completely flush the system following treatment to remove disinfectant that could be poisonous to plants.

Disinfect the greenhouse by spraying all surfaces with a 5- to 10-percent solution of household bleach. You can get this mixture by adding 1 gallon of bleach to 19 gallons of water (5 percent), or 1 gallon of bleach to 9 gallons of water (10 percent). After about 15 minutes, rinse sprayed surfaces with plain water. This treatment is effective for most greenhouse disease microorganisms, but you must use it in combination with a strong sanitation program.

If you produce your own transplants, use disease-free seeds, sterile growth media, and containers. Remove and destroy transplants that do not look normal.

After crop installation:

Have a clean-up room to disinfect hands and clean shoes. In short, use any practice available to prevent introducing diseases into the greenhouse.

Restrict use of tobacco products if you are growing a ToMV-susceptible variety.

Frequently disinfect tools and other equipment with bleach at the rate of 2 gallon per 10 gallons of water. Dip for 5 to 10 seconds, drain, and use without rinsing.

Keep a "clean strip" around the outside of the greenhouse to reduce populations of thrips, aphids, and other insects that could be sources of virus introduction.

Consider using insect-barrier screens to cut down on movement (into the greenhouse) of thrips, aphids, and other possible virus-carriers.

Observe plants constantly for any evidence of disease development. Promptly remove diseased plants, and remove foliage that may be seriously diseased or no longer contributing to plant growth. You must destroy diseased plants and diseased plant parts or carry them far enough away from the greenhouse so that they won't be a source to reintroduce the disease into the greenhouse.

Fungicides

The need for week-to-week fungicide application decreases if you follow these procedures: use sanitary practices to limit fungus spores that could spread the disease from previous crops; control the greenhouse environment to prevent long periods of high humidity; and use other cultural practices as previously described.

Many fungicides are now labeled for use on greenhouse tomatoes. As with insecticides, the new EPA interpretation of fungicide labels states that if the product is labeled for use on tomatoes, and the product label does not specifically prohibit the use of the product in greenhouses, the fungicide can be considered legal to use on greenhouse tomatoes.

Also, you must completely read the product label before use. Some fungicides once labeled for use on greenhouse tomatoes are no longer legal. One example is Exotherm Termil (chlorothalonil smoke bomb). If a grower has an older container with label attached, it will be labeled for use on greenhouse tomatoes, and that product would be legal to apply. If the grower recently purchased a container of Exotherm Termil, they will not find tomatoes on the label. The reason for this is that an additional chemical was added to the product, and this chemical is not labeled for use on any food crop. Thus, a newly purchased container of Exotherm Termil is not legal to apply to greenhouse tomatoes.

Fungicides Labeled for Greenhouse Tomato Use

Active Ingredient and Percent Concentration	Trade Name(s)	Use Rate	Diseases Controlled	REI (hrs)	PHI (days)	Remarks
Zinc + manganese ethylene bisdithiocarbamate (75%)	Mancozeb Dithane	1.5 – 2.0 lb product per 43,560 sq ft of area	Anthracnose Early blight Leaf mold Septoria leaf spot Late blight	24	5	Do not apply within 5 days of harvest.
Eiridiazole (44.3%)	Terramaster 4 EC	6 – 7 fl oz per acre applied in a 0.01% solution through drip irrigation	Pythium and Phytophthora root rot	12	3	Do not apply within 3 days of harvest.
Propamocarb hydrochloride (66.5%)	Previcur Flex	Mix a 1:1,000 solution and apply 1 oz per plant	Pythium and Phytophthora root rot	12	5	Do not apply within 5 days of harvest.
Fenhexamide (50%)	Decree 50 WDG*	1.2 lb product per 43,560 sq ft of area in sufficient water for thorough coverage	Botrytis gray mold	4	1	Can be applied up to 1 day before harvest.
Pyrimethanil (54.6%)	Scala SC*	7 oz product per 43,560 sq ft of area	Early blight Botrytis gray mold	12	1	Can be applied up to 2 days before harvest. Greenhouse must be ventilated after application to prevent poisoning the plants.
Boscalid (70%)	Endura*	3.5 oz product per 43,560 sq ft of area	Target spot suppression of Botrytis gray mold	12	0	Can be applied up until the day of harvest.
Famoxadone (25%) Cymoxanil (25%)	Tanos*	6 – 8 oz product per 43,560 sq ft of area	Early blight Target spot Suppression of Bacterial spot and speck	12	3	Can be applied up until 3 days before harvest. Consult label for use directions for specific diseases.
Dicloran (75%)	Botran 75W Botran 75WSB Clortran	1.0 lb per 43,560 sq ft of area	Botrytis gray mold (Sclerotinia) Stem rot (Timber Rot)	12	10	Apply from the soil line only up to 24 inches high. Allow 10 days from last application until harvesting. Do not make more than 4 applications per crop.
Myclobutanil (40%)	Nova 40W*	2.0 – 4.0 oz per 43,560 sq ft of area	Powdery mildew	24	0	Do not apply more than 1.25 lb per acre per crop.

Cooper Salts of Fatty and Rosin Acids (48%)	Copper Fungicide Liquid Copper Fungicide	Consult label	(Erwinia) Bacterial soft rot (Pseudomonas) Bacterial speck (Xanthomonas) Bacterial spot Powdery mildew	Until sprays have dried.	0	Can be applied up until the day of harvest.
Copper Hydroxide (23%) Copper Hydroxide (23%) Copper Hydroxide (77%) Copper Hydroxide (53%) Copper Hydroxide (53%) Copper Hydroxide (61%) Copper Hydroxide (23%) Copper Hydroxide (37%)	High Yield Copper Fungicide Natural Guard Copper Fungicide Kocide 101 W/P Ag. Fungicide Kocide 2000 DF Fungicide Kocide 2000 T/N/O Fungicide Kocide DF Ag. Fungicide Kocide LF Fungicide Champ Formula 2 Flowable	Consult label	(Pseudomonas) Bacterial speck (Xanthomonas) Bacterial spot (Clavibacter) Bacterial canker	24	0	Some products are OMRI approved. Can be applied up until the day of harvest.
Mn ethylenebisdithio carbamate (75%) Mn ethylenebisdithio carbamate (80%) Mn ethylenebisdithio carbamate (37%)	Maneb 75 DF Maneb 80 Manex	1.5 – 3.0 lb per 43,560 sq ft of area	Anthraxnose (Fulvia) Leaf mold (Alternaria) Early blight (Phytophthora) Late blight (Septoria) Leaf spot (Stemphylium) Gray leaf spot	24	5	Do not apply within 5 days of harvest.
Neem Oil (70%) Neem Oil (70%) Neem Oil (70%)	Green Light Neem Conc. Garden Safe Fungicide 3 Conc. Triact 70 Broad Spectrum	1:200 up to 1:100 solution. Apply just before runoff.	Powdery mildew (Fulvia) Leaf mold Botrytis gray mold	Until sprays have dried	0	OMRI approved. Toxic to bees. May be used up to day of harvest.
Sulfur (80%)	Microthiol Dispers	5 – 10 lb per 43,560 sq ft of area	Powdery mildew	24		OMRI approved. Do not apply if temperature exceeds 90 degrees.

Hydrogen Dioxide (27%)	Oxidate	1.0 gal per 100 gal of water. Apply 50-100 gal water per 43,560 sq ft of area.	(Alternaria) Early blight (Fulvia) Leaf mold (Phytophthora) Late blight Powdery mildew	0	0	May be applied up until day of harvest. Do not use chlorinated water to mix this product.
Harpin Protein (3%)	Messenger	2.25 – 4.50 oz per 50 gal of water applied as a drench to seedlings. Foliar sprays at 2-week intervals.	Bacterial spot (Xanthomonas) Bacterial speck (Pseudomonas) Bacterial speck	4	0	
Acibenzolar-methyl (50%)	Actigard	0.33 – 0.75 oz per 43,560 sq ft of area	Bacterial Spot Bacterial Speck	12	14	Start out with low rate and increase to high rate over the 6-week spray period.
Trichoderma harzianum (1.15%)	Plant Shield	Suspend 6 – 12 oz product in 100 gal of water. Apply 50 – 100 gal per 800 sq ft area. 0.5 – 1.0 oz product per gal water for foliar spray.	Pythium root rot (soil drench) Botrytis Gray mold (foliar spray)	0	0	OMRI approved. Plant shield uses a beneficial fungus as a biological control agent.
Bacillus subtilis (1.34%)	Rhapsody AS	4 – 8 qt per 100 gal of water applied to 43,560 sq ft area	Early blight Late blight Powdery mildew (Xanthomonas) Bacterial spot	0	0	Rhapsody uses a bacterium as a biological control agent.
Coniothyrium minitans (5.3%)	Contans WG	0.75 – 1.5 oz per 1,000 sq ft applied to growing medium	Timber rot or White mold (Sclerotinia)	4	0	OMRI approved.
Stereomyces griseoviridis (4%)	Mycostop	1 – 2 g per 100 sq ft of area in enough water to cover root zone	Pythium- suppression Rhizoctonia- suppression Phytophthora- suppression	4	0	OMRI approved. Mycostop uses spores and mycelium of fungus as a biological control agent.
Sitreptomycin sulfate (1.7%)	Agri-Mycin	16 oz/100 gal	Bacterial spot	12	0	OMRI approved.

Read labels for these products carefully. Each product has tomato on the label and does not prohibit use in a greenhouse. Product labels constantly change to reflect legal use in greenhouse tomato production. For example, some products have a special use permit only in certain states. You are responsible for determining if the product is legal in your state. Another concern is the age of the product you are using. For example, Quadris purchased one year ago is legal for use in the greenhouse according to EPA interpretation of the label. Quadris purchased within the last several months has a restriction specifically stating that the product can not be used in a greenhouse.

REI, Restricted Entry Interval, is time that must pass after an application before workers may enter the treated area.

Personal Protective Equipment, PPE, that must be worn for early entry is specified on the product label.

PHI, Preharvest Interval, is the least amount of time that must pass between the last application of the product and harvest.

Pesticide Storage

Keep pesticides where children, adults who are unfamiliar with pesticides, and animals cannot get to them. Store all pesticides under lock and key. Do not store with or near feed, seed, clothing, or other articles. Keep storage areas lit well and ventilated with temperatures that will not go below freezing. Store in an area that is fire-resistant and has an exhaust fan. Place warning signs on all entrances and keep doors locked. Store products in their original containers, and mark the month and year of purchase on all packages to determine their age. Keep an up-to-date list of pesticide products.

Worker Protection for Greenhouse Employees

Read and follow label directions.

Use all personal protective equipment (PPE) according to the label.

Use extreme care in enclosed areas. Use a respirator or self-contained breathing device.

Ventilate greenhouse properly before reentry.

Post reentry periods according to the Worker Protection Standard.

Use proper care and maintenance of personal protective equipment. Inspect gloves for leaks, and wash them off after use and before removal.

Know poisoning symptoms for material being used.

Work in pairs or have someone check on you and other workers.

The information given in this publication is for educational and planning purposes only. Because the registration status of pesticides constantly changes, always read and follow current label directions. Specific commercial products are given as examples only, and reference to certain commercial products or trade names is made with no discrimination against other products that may also be suitable and have label clearances.



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