Greenhouse Tomatoes

Pest Management in Mississippi

MISSISSIPPI STATE UNIVERSITY EXTENSION

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 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 wind-borne 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 and cull and overripe 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 10–20X 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 greenhouse 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. 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. Applying pesticides at excessive rates can result in plant injury and other problems.

Most insect pests of greenhouse tomatoes occur on the undersides of leaves, and you will not get good control unless you spray the bottoms of the leaves. Because pest populations are often hightest on the lower, older leaves, it is especially important to be sure to treat the undersides of lower leaves. Using adequte spray volume and taking the time necessary to treat the leaf undersides thoroughly, expecially lower leaves, is critical to achieving good control with insecticide sprays. Poor control is often the result of poor, hastily made applications.

Major Insect Pests

Aphids

Green peach aphids — *Myzus persicae*
Potato aphids — *Macrosiphum euphorbiae*
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 vegetable 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*, flonicamid, paraffinic oil, potassium salts of fatty acids, pyrethrins

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. Flonicamid works by paralyzing the aphids' mouthparts and making it impossible for them to feed.

Whiteflies

Silverleaf whiteflies *Bemesia tabaci*
Greenhouse whiteflies *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 one-sixteenth of an 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. According to research conducted in Florida, populations of silverleaf whitefly that exceed five nymphs per 10 leaflets are sufficient to cause irregular ripening. Thus, **treatment is recommended when populations of silverleaf whitefly reach or exceed five nymphs per 10 leaflets.** Higher populations of greenhouse whiteflies can be tolerated without experiencing irregular ripening.

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 whiteflies, 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 four to seven 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 manage 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

acetamiprid, azadirachtin, *Beauvaria bassiana*, buprofezin, cyantraniliprole, imidacloprid, *Isaria fumosorosea*, paraffinic oil, potassium salts of fatty acids, pyrethrins, pyriproxyfen

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. 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) 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.

The systemic growing-media treatments, imidacloprid and acetamiprid, are useful whitefly treatments that can be applied through the irrigation water. Only one application is allowed per crop. These treatments are slow-acting but provide relatively long-term control. Note that acetamiprid (Tristar) can be used only on plants growing in perlite or other soil-less growing-media, while imidacloprid (Admire) can be used only on plants growing in field-type soils or potting media.

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 one-tenth of an 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 one-sixteenth of an 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 four 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 two weeks, and a generation can be completed in about four 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

acetamiprid, pyrethrins

This pest is susceptible to contact sprays of pyrethrins, but make two applications at seven-day intervals. 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 one-sixteenth of an 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 eight to twelve days before moving to the ground, finding a protected location, and entering the pupal stage, which lasts three to seven 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 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, *Beauvaria bassiana*, chlorfenapyr, 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. Chlorfenapyr is also very effective against thrips. Paraffinic oil, potassium salts of fatty acids, and pyrethrins provide contact control of thrips. Azadirachtin is a botanically derived insect growth regulator. *Beauvaria bassiana* is a biopesticide mainly used to control whiteflies, but it also provides some control of thrips.

Leafminers

Vegetable leafminers *Liriomyza sativae*
Serpentine leafminers *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 one-twelfth of an 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 three 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 five to twelve 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. 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 one-eighth of an 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 one-fifth of an 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 three to forty on the surface of the growth medium. Eggs hatch within three to six days, and larvae begin feeding on fungi, root hairs, and roots. Larvae mature in about two weeks, construct a pupal case, and remain there about three to seven days before emerging as adults. Adults live about one 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*, 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, 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 mites *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 five to seven days. Adult females may live one to two 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

acequinocyl, bifenzate, chlorfenapyr, etoxazol, fenproximate, paraffinic oil, potassium salts of fatty acids

Specific miticides, such as acequinocyl, bifenzate, chlorfenapyr, etoxazol, or fenproximate 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 millimeter 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 russeting 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 eggplants and peppers, 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 seven 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

chlorofenapyr, fenproximate

Sulfur is one of the products traditionally recommended for chemical control of tomato russet mites, but more specific miticides, such as fenproximate or 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 one-fourth of an 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 brown heads. Adults are small, gray moths that are about one-third of an 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. Tomatoes are the preferred host, but this caterpillar also attacks eggplants and potatoes, 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 Pinworm Control

spinosad, cholorfenapyr, cyantraniliprole

Specific caterpillar insecticides, such as spinosad, chlorfenapyr, or cyantraniliprole, 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 fruitworms	*Helicoverpa zea*
Armyworms	*Spodoptera* spp.
Cabbage loopers	*Trichoplusia ni*

There are several species of large caterpillars (over one 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 1½ inch 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 one-fourth of an inch long). Tobacco budworm is a smiliar 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 two 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 one 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 three to seven 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 eight to eleven 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

Bt kurstaki, chlorfenapyr, cyantraniliprole, spinosad

Specific caterpillar treatments, such as spinosad, provide good control when applied in a timely and appropirate manner. Chlorofenapyr will contol 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 four 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.

Table 1. Insecticides, Miticides, and Molluscicides for Greenhouse Tomatoes

Active Ingredient and Percent Concentration	Trade Name (Supplier)	Use Rate	Pests Controlled	REI (Hours)	PHI (Days)	Remarks
Acequinocyl 15.8%	Kanemite 15 SC (Arysta)	31 fl oz/acre	spider mites	12	1	Controls spider mites. Do not use a surfactant or adjuvant. Do not exceed two applications per crop. Allow a minimum of 21 days between treatments. Does not control russet mites.
Acetamiprid	TriStar 8.5 SL (Cleary Chemicals)	1.25 fl oz/1,000 plants	aphids, whiteflies, psyllids, thrips	12	1	Apply as a growing-media drench or through irrigation according to label. Do not apply more than one application per year. Apply only to plants growing in rock wool, perlite, other soil-less growing media, or plants growing hydroponically. Do not apply to plants growing in field-type soils or potting media. This is a neonicotinoid type product. Acetamiprid will control leaf-feeding thrips, but is less effective on thrips in blooms.
Azadirachtin 1.2%	Azatrol 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.
Azadirachtin 3%	Azatin XL (OHP)	8–21 fl oz/acre	whiteflies, aphids, leaf miners, thrips, fungus gnats	4	0	These are botanically based products that act as insect growth regulators. They may be applied as a foliar spray for pests on leaves, or as a growing media drench for fungus gnats. Molt-X is OMRI approved.
	AzaGuard (BioSafe)	10–21 fl oz/acre				
	Molt-X (BioWorks)	10 fl oz/100 gal				
Azadirachtin 1.2% + Pyrethrins 1.4%	Azera	53–107 fl oz/100 gal (1–2 fl oz/gal for compressed air sprayers)	whiteflies, aphids, leaf miners, thrips, caterpillars, fungus gnats	12	0	Azera is OMRI approved. This is a pre-mix containing azadirachtin and natural pyrethrins. Reapply as needed, but allow 5–7 days between treatments. May be applied as a media drench to control fungus gnats.
Bacillus thuringiensis aizawai, 54% 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.
Bacillus thuringiensis 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.**
Bacillus thuringiensis kurstaki, 54% 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.
Beauveria bassiana Strain GHA, 11.3% liquid or 10.9% liquid	BotaniGard ES (BioWorks) or Mycotrol O (BioWorks)	1–2 qt/100 gal	whiteflies, aphids, thrips, psyllids	4	0	Mycotrol O is OMRI approved. BotaniGard ES is not organic. These are slow-acting biopesticides. Apply successive applications at 3- to 7-day intervals. This is a fungal disease, mainly used to control whiteflies, but it will also infest other listed insects.

Table 1. Insecticides, Miticides, and Molluscicides for Greenhouse Tomatoes

Active Ingredient and Percent Concentration	Trade Name (Supplier)	Use Rate	Pests Controlled	REI (Hours)	PHI (Days)	Remarks
Bifenazate, 22.6% SC	Floramite SC (OHP)	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 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, 2 SC	Pylon (Olympic Hort.)	6.5–13 fl oz/acre	spider mites, tomato russet mites, caterpillar pests, thrips, tomato pinworms	12	0	Chlorfenapyr is a miticide that moves from the top side of the leaf to the bottom. It also controls thrips, leaf-feeding caterpillar pests, thrips, caterpillars, and tomato pinworms. Do not use on tomato varieties with mature fruit diameter less than 1 inch. Allow at least 5–7 days between applications. Do not exceed two consecutive applications. Do not apply more than three applications per crop.
Cyantraniliprole 10.2% liquid	Exirel (0.83 lb ai/gal)	13.5–20.5 fl oz/acre	whiteflies, tomato psyllids, caterpillars	12	1	This is a useful new product to include in a whitefly control rotation program. Include a spray adjuvant as specified on label. Allow a minimum of 7 days between applications. Do not exceed 0.4 lb ai per acre.
Etoxazol 5%	TetraSan 5 WDG (Valent)	8–20 oz/100 gal	spider mites	12	1	Controls eggs and nymphs of spider mites. Do not use a surfactant or adjuvant. Do not exceed two applications per crop. Allow a minimum of 21 days between treatments. Does not control russet mites.
Fenproximate 5% SC	Akari 5SC	2 pt/100 gal	spider mites, tomato russet mites, potato psyllids	12	1	Rotate with other miticides. Do not exceed two applications per growing season.
Flonicamid 50% SG	Beleaf 50 SG (FMC)	2.8–4.28 oz/acre	aphids	12	0	This product is specifically for aphids. Beleaf provides suppression of whiteflies. Do not exceed two applications per crop. Allow a minimum of 7 days between treatments.
Imidacloprid	AdmirePro (4.6 lb/gal) (Bayer CropScience)	0.6 fl oz /1,000 plants	aphids, whiteflies	12	0	Apply in a minimum of 16 gallons of water as a growing-media drench or through irrigation according to label. Do not apply more than 1 application per year. Apply only to plants growing in field-type soils or potting media. Do not apply to plants growing in rock wool, perlite, 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. Media drench treatments of imidacloprid have long-term adverse effects on bumble bees.
	Macho 2.0 FL	1.4 fl oz /1,000 plants				

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Active Ingredient and Percent Concentration	Trade Name (Supplier)	Use Rate	Pests Controlled	REI (Hours)	PHI (Days)	Remarks
Iron phosphate 1%	Sluggo (Monterey)	1 lb/1,000 ft^2	slugs	NA	NA	OMRI approved. Do not apply directly to plants.
Isaria fumosorosea 20% (Apopka Strain 97)	Preferal (SePro) PFR-97 (Certis)	14–28 oz/100 gal	whiteflies, aphids, thrips, spider mites	4	0	OMRI approved. Most effective when relative humidity is maintained at 80% or higher for 8–10 hours post-treatment. Not effective under low humidity situations. Make repeated sprays at 3- and 7-day intervals over a 2- to 3-week period.
Metaldehyde 2%	Ortho Bug-Geta Snail & Slug Killer (Ortho)	1 lb/2,000 ft^2	slugs	NA	0	Do not apply directly to plants.
Metaldehyde 0.13 bait	No Escape Slug & Snail Killer (Bonide)	1 lb/1,000 ft^2	slugs	NA	NA	Do not apply directly to plants.
Mineral Oil 80%	SuffOil-X TriTek	1–2 gal/100 gal	whiteflies, aphids thrips, mites	4	0	OMRI approved. Provides control by suffocating pests. Spray must contact the pest directly.
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	apids, 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.
Pyrethrins 1.4% liquid	Pyganic (King)	16–32 fl oz/30 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 (Whitmire Micro-Gen)	One 6-oz can/ 4,500–9,000 sq ft	fungus gnats, aphids, whiteflies, psyllids	12	NA	Total release aerosol fogger for knockdown of adult insects. Available in 20-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.

Table 1. Insecticides, Miticides, and Molluscicides for Greenhouse Tomatoes

Active Ingredient and Percent Concentration	Trade Name (Supplier)	Use Rate	Pests Controlled	REI (Hours)	PHI (Days)	Remarks
Pyrethrins, 6% + PBO 60%	Pyreth-It (Whitemire 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%	Pyrenone 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.
Pyriproxyfen 11.23% EC	Distance (Valent)	6 fl oz/100 gal	whiteflies (immature only)	12	1	This is an insect growth regulator-type product that is especially useful against whiteflies. It does not control adults but interferes with development of immatures. Must be applied as a foliar spray. 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 22.5%	Entrust SC (Dow AgroSciences)	3–6 fl oz/acre	caterpillar pests, flower thrips, leaf miners	4	1	OMRI approved. Spinosad is one of the most effective treatments available for control of caterpillar pests and thrips in greenhouse tomatoes. Do not apply more than two successive sprays before rotating to a different class of chemistry. Do not apply to tomatoes grown for transplant.
Sulfur, 90%, SP	Microfine Sulfur (Tiger-Sunbelt 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.

*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 cannot be used in a greenhouse.

REI, restricted entry interval, is the time that must pass after an application before workers may enter the treated area.

PPE, personal protective equipment, 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.

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 than fluid ounces. There are about 29.6 milliliters in one fluid ounce. So 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 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. So 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 grams per acre. 172 divided by 44 = 3.9 grams per 1,000 square feet.

Disease Identification and Management

To develop a successful greenhouse tomato disease management program, a grower must be aware of and be able to recognize the diseases that may affect the crop and the conditions that promote disease development. It is also important to scout a crop regularly and often for signs and symptoms of disease. ***Signs*** (the physical presence of pathogens; e.g., fungal mycelium or sclerotia) and ***symptoms*** (the plant's reaction to infection by a pathogen; e.g., chlorosis, wilting, leaf spots) of greenhouse tomato diseases may be present on roots, stems, leaves, and fruit. While some symptoms are common to several diseases, it is usually possible to identify a few of the more common diseases by their key signs or symptoms. When these key signs or symptoms are not present, it is often necessary to submit a physical sample to a plant diagnostic laboratory or specialist for examination to obtain an accurate diagnosis. Descriptions of the signs and/or symptoms, including any key signs and/or symptoms, of the most common diseases that occur in greenhouse tomatoes are included below.

If you have trouble identifying a disease, contact your local county Extension agent. He or she will collect information, such as a description of the symptoms, recent applications of pesticides, varieties affected, and production practices. The agent may take, or ask you to submit, digital photos of the problem. Information explaining the best types of photos to take for assistance with plant disease problems can be found in publication P3022 *Taking Photos of Plant Disease Problems*. This information will help diagnose the problem and aid in developing management recommendations.

It is possible that you may be asked to collect and bring a specimen to the Extension office. Your county agent can guide you on how to correctly collect and package samples for diagnosis. Instructions for collecting and packaging plant disease specimens for diagnosis may also be found in publication M1562 *How to Collect and Package Plant Disease Specimens for Diagnosis*. Specimens may also be mailed directly in to the Extension Plant Diagnostic Lab for diagnosis. When submitting a specimen, be sure to fill out Form 1139 *Plant Disease Sample Submission Form* with as many details as possible, and include it with your sample. These details can be useful for accurate and faster diagnosis.

In more difficult situations, your local county Extension agent may decide that an MSU Extension specialist should examine the problem directly and schedule a site visit.

Disease Identification

Fungal and Fungal-like 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. Plants are generally more vulnerable during fruit bearing.

Key sign: Brown or gray fuzzy fungal growth present on infected tissues.

All plant parts can be affected. Tan or gray ***lesions*** (localized areas of diseased tissue) typically form at the tips of leaflets and become covered with brown or gray fungal growth. Infected leaves typically collapse and wither. 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. If viewed with a hand lens, spore-bearing structures that look like bunches of grapes may be seen on the infected tissue. The causal fungus does not actively attack healthy tissue, and stem invasion occurs through wounds, such as those resulting from pruning. The tan ***cankers*** (defined, dry, necrotic lesions) that form along the stem, commonly around pruning wounds, may be large and often cause wilting of the tissue above the canker and early plant death. Under humid conditions, distinct masses of fungal growth form on the surface of the cankers. An unusual symptom associated with this disease is the production of "ghost spots," small whitish rings or halos that develop on the fruit. These "ghost spots" are spots where *Botrytis* spores germinated, but failed to infect the fruit.

Early blight (*Alternaria solani* and *A. tomatophila*) is a common problem in field-grown tomatoes but sometimes causes problems in greenhouse-grown tomatoes. Disease development is favored by high humidity and mild temperatures.

Symptoms of early blight may occur on leaves, stems, and fruit. Circular, brown lesions, up to 2 inches in diameter, develop on infected plant tissues. Concentric rings are often visible in each lesion. The leaf tissue surrounding the brown lesions may be chlorotic (yellow).

Fusarium crown and root rot (FCRR, *Fusarium oxysporum* f. sp. *radices-lycopersici*) was first found in Mississippi greenhouse tomatoes in the late 1980s. This disease is favored by cooler temperatures and can spread quickly in a greenhouse.

Symptoms of FCRR include stunted growth and wilting on sunny days, especially if plants have heavy fruit loads. After initially infecting secondary roots, the FCRR fungus moves into larger roots and eventually invades the plant's vascular system. 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. Look for a reddish discoloration in the outer fourth of the stem inside the vascular tissue. The vascular tissue of plants infected with the FCRR pathogen is typically dark to reddish-brown. This discoloration may extend as high as 12 to 18 inches above the soil line.

Leaf mold (*Passalora fulva*, formerly *Fulvia fulva* and *Cladosporium fulvum*) was a common and severe problem in the early 1970s because resistant varieties were not available. Today, varieties that have resistance to various races of the leaf mold fungus are available. Infection by the leaf mold fungus occurs when relative humidity remains at 90 percent or higher for several hours.

Key sign/symptom: Pale green or yellow lesions with irregular margins on the upper surface of leaflets and olive green, velvet-like fungal growth on the underside of the leaflets directly beneath lesions.

Leaf mold is a foliar disease. Symptoms begin on lower, older leaves but progress to younger leaves over time. Infected leaves become yellow-brown and drop prematurely. Defoliation progresses up the plant.

Powdery mildew (*Leveillula taurica* and *Oidium neolycopersici*) can be found throughout North America, but it has not been a widespread greenhouse tomato problem in Mississippi. The pathogen *L. taurica* is restricted to areas with semi-arid or arid environments; however, the pathogen *O. neolycopersici* favors humid environments and can be problematic in greenhouses.

Key sign: White patches of fine, powdery growth on the upper surface of leaflets.

Powdery mildew is a foliar disease. Patches of fungal growth may be up to 2 inches in diameter and generally appear on the oldest foliage. Severe infections weaken the plants and can reduce yield. Light green or bright yellow, irregularly shaped lesions typically appear on the upper surface of tomato leaflets infected with *L. taurica*.

Pythium root rot (*Pythium* spp.) can be a severe problem in greenhouses. The various species of *Pythium* that cause problems in tomatoes are easily introduced into the greenhouse via contaminated water and soil clinging to shoes and tools. A common source of *Pythium* is a nonsterile growth medium, such as river sand piled on bare ground that becomes contaminated from underlying soil during wet conditions. Pythium root rot occurs most often when too much water accumulates around roots. *Pythium* is one of a group of fungal-like pathogens (oomycetes) commonly called water molds. *Pythium* is most aggressive when the growth medium is too heavy and drainage is poor. When this occurs, the fungus attacks juvenile roots and eventually the main root mass. The problem is enhanced by overcast weather.

Plants with Pythium root rot are often wilted and stunted with yellow, weak foliage. The roots of infected plants are typically chocolate-brown or black. Infected plants generally do not die and often produce new roots if moisture problems are corrected. Early symptoms may start with a slight wilt during hot days and plant recovery at night. The wilting may become worse until no plant recovery occurs at night and the plant dies.

Target spot (*Corynespora cassiicola*) can be another problem in greenhouse tomatoes.

Early symptoms of target spot first appear on foliage as small, water-soaked lesions on the upper surface of older leaves. These lesions rapidly grow to form light- to dark-brown circular lesions that take on the appearance of a target. Chlorotic halos develop around individual brown lesions on leaflets. Lesions may also appear on stems and fruits. Symptoms on fruit begin as sunken, pinpoint-sized, brown lesions. These lesions enlarge and develop into crater-like spots that continue to grow and will crack open as fruit ripens. This disease may move quickly from foliage to fruit, causing a large reduction in the yield of marketable fruit.

Timber rot (*Sclerotinia sclerotiorum*), also called white mold or Sclerotinia stem rot, has been present in Mississippi greenhouse tomatoes.

Key signs: White fungal growth on the plant stem and black sclerotia (resembling rat droppings) on or inside the plant stem at the site of the lesion.

Timber rot begins as a water-soaked lesion on the stem of the plant, usually close to the floor and within 2 to 3 feet of the base of the plant. White fungal growth may be present on the stem when environmental conditions are favorable. Infected plants turn yellow (youngest leaves), wilt, and die quickly. If a cut is made through the lesion on the stem, hard, black, rock-like structures (sclerotia) may be present inside the stem. These ***sclerotia*** (fungal survival struc-

tures) can fall onto the floor or into the growing medium and serve as a source of inoculum for the next season's crop.

The white color of the fungal mycelium and the dark-colored, hard sclerotia are what distinguish timber rot from gray mold.

Bacterial Diseases

Bacterial wilt (*Ralstonia solanacearum*) can be a devastating disease of both field and greenhouse tomatoes. This bacterial species is divided into five races (subgroups), not all of which are present in the United States. The race that commonly infects tomatoes is Race 1 and is endemic throughout the southeastern United States. However, the diseases caused by some races not in the United States are important enough that all races of the pathogen are considered to be select agents by the USDA Animal and Plant Health Inspection Service (APHIS). As such, samples testing positive for this bacterium must be handled according to protocol, and reports must be submitted to the USDA APHIS.

Key sign/symptom: Vascular discoloration and bacterial streaming in plants that exhibited rapid and permanent wilting followed by plant death.

Plants infected with the bacterial wilt pathogen rapidly wilt and die without showing symptoms of chlorosis (yellowing) or leaf necrosis (death). A brown lesion may be visible on the outside of the stem near the base of the plant. When cut near the base of the stem at the soil/media line, the inside of the stem may be dark and water-soaked. In plants with advanced infections, the stem may be hollow.

Plants suspected to have bacterial wilt can be tested for bacterial streaming. This test is easy to perform, and results may be seen in only a few minutes. While bacterial streaming does not occur 100 percent of the time in plants with bacterial infections, it can be used to confirm a bacterial infection. Tomatoes with bacterial wilt typically exhibit profuse streaming. Follow these steps to test for bacterial streaming:

1. Cut a 2-inch-long section from the base of an affected stem (near the soil/media), and remove any soil/media from the outside of the stem.
2. Suspend the stem (using a wire hanger, nail, etc.) in a clear container of water so that the base of the stem is a good distance from the bottom of the container, and place this setup where it will be left undisturbed.
3. Observe the setup after a few minutes for a thin, milky stream flowing from the stem to the bottom of the container.

Streaming is best seen when the container is at eye level, with light coming from behind.

Tomato pith necrosis (*Pseudomonas* spp.) is sometimes referred to as bacterial hollow stem. Affected plants sometimes wilt and show a slight yellowing of lower foliage. Pathogen spread occurs via contaminated pruning and harvesting equipment.

Key symptoms: Brown, sunken, necrotic (dead) cankers on stems with a pith that is severely degraded, hollow, or dark brown to black, or that has a ladder-like appearance.

Plants with pith necrosis may exhibit a slight chlorosis (yellowing) of lower foliage and wilting.

Viral Diseases

Tomato mosaic (*tomato mosaic virus*, ToMV) was an important disease until the introduction of resistant varieties in the early 1980s. Today, since most varieties are resistant to ToMV, a strain of tobacco mosaic virus (TMV), this disease is no longer a major threat to production. However, growers who use varieties that are not resistant to ToMV need to be familiar with the symptoms of this disease so that immediate action can be taken if it appears.

There is a wide array of possible symptoms associated with this disease, making a ToMV diagnosis, based on symptoms, difficult. Symptoms depend on the variety, age of the plant at the time of infection, and environmental conditions. Plants infected with ToMV become stunted, and leaves may have mild to severe yellow-green spots, crinkles, ridges, strings, or curls. Streaks of dead tissue may develop in stems. Generally, fruit shows no symptoms; however, some strains may cause internal browning, pitting, or severe mottling.

Because ToMV spreads easily through pruning, fruit harvesting, and other routine activities, when ToMV is suspected, samples should be submitted to a disease diagnostic laboratory for testing, and diseased plants should be removed immediately.

Tomato spotted wilt (*tomato spotted wilt virus*, TSWV) can be a widespread problem in greenhouse tomatoes. Like ToMV, diagnosis of TSWV can be difficult since symptoms can be numerous and can vary. Symptoms of tomato spotted wilt can also be confused with symptoms caused by other viral, fungal, or bacterial pathogens or by nutritional disorders. The virus is moved from one plant to another by several species of thrips, most commonly the western flower thrips. Scouting for and controlling thrips populations is

important to prevent the spread of TSWV. A "clean strip" free of broad-leaved weeds should be maintained around the perimeter of the greenhouse since many weedy plants can harbor TSWV.

Symptoms of TSWV can include small, dark-brown leaf spots in the upper portion of the plant that may be arranged in a "ringspot" pattern, dark streaking in petioles and stems, stunted growth of terminals, and brown or black lesions on distorted fruit.

Immunostrip test kits are available to check for the presence of TSWV in tomatoes. These kits are inexpensive, dependable, and easy to use. Contact your county Extension office to find out where test kits can be purchased. Samples of plants can also be submitted to a disease diagnostic laboratory for testing. Plants suspected to be infected with TSWV should be removed.

Tomato yellow leaf curl (*tomato yellow leaf curl virus*, TYLCV) is a destructive virus disease that was first observed in Mississippi in greenhouse tomatoes in 2001. This disease is transmitted by whiteflies. Commonly grown Mississippi greenhouse tomato varieties do not have resistance to this disease. Once infection occurs, the virus prevents further plant development. Flowers and fruits are not produced following infection, resulting in total crop loss. Scouting for and controlling whiteflies are important methods of preventing further spread of TYLCV.

Symptoms of the disease begin to appear 10 to 12 days after infection. Leaves in the top of the plant develop interveinal chlorosis (yellowing between the veins), and the sides of the leaves curl upward. The leaves may appear crinkled. The symptoms will be subtle at first, but yellowing will increase over time and become very noticeable.

Miscellaneous Diseases

Other diseases that are less common in greenhouse tomatoes but that are detected from time to time could present problems in a crop. Contact your local county Extension agent for assistance in diagnosing diseases that do not fit the "key sign or symptom" approach.

Disease Management

Diseases caused by bacteria, fungi, and viruses can quickly destroy a crop of greenhouse tomatoes when conditions are favorable. However, if a combination of recommended disease management practices is used as part of an integrated pest management (IPM) program, diseases can be successfully managed. Biological, cultural, environmental, sanitation, and chemical management practices may all be necessary since no single practice effectively manages all diseases affecting the crop.

Biological Management

Biological management, through the use of disease-resistant varieties, is the most economic and effective method of handling several significant diseases. 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 of the diseases that used to be limiting factors in production.

The disease-resistance package (the combination of all disease resistance present) in a particular variety is often listed on seed packages and in seed company catalogs or websites. Disease-resistance codes are used to indicate to which diseases a particular variety has resistance. For example, L may stand for leaf mold resistance, while TSWV typically stands for *tomato spotted wilt virus* resistance. Consult the company's key of disease-resistance codes for code definitions. Heirloom varieties, which are favored by some greenhouse tomato growers, generally do not have resistance to disease.

Biological products are available for use in managing diseases of greenhouse tomatoes. These products work best when use begins prior to the appearance of disease. Some biological products are provided in **Table 2** and in publication P2036 *Organic Vegetable IPM Guide*. Additional biological products may be found in the latest edition of the Southeastern U.S. Vegetable Crop Handbook (available at ***http://www.thepacker.com/guides/Pest-production-guides***).

Cultural Management

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

Because a greenhouse is a protected system, it is possible to manipulate the environment in the greenhouse. This includes the temperature as well as the relative humidity. Regulating the relative humidity is critical since moisture is the main factor influencing plant infection by the fungi responsible for gray mold, leaf mold, and timber rot. 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. Warm air holds more moisture than cool air. Thus, during warm fall and spring days, the air inside the greenhouse picks up moisture. As the air cools in the evening, its moisture-holding capacity drops. When this happens, the dew point is reached and moisture (condensation) begins to form on plant surfaces. Condensation can be reduced or eliminated by practicing the following methods:

- When the heat comes on in the late afternoon, keep the ventilators open about 1 inch or keep the exhaust fans running on low capacity. This allows cold, dry air to enter the greenhouse and warm, moist air to leave. The cold, drier air that enters the greenhouse is heated or further dried. After 5 to 10 minutes, close the ventilators or turn the fans 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 humid, 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, temperatures no lower than 70°F limit development of gray mold. FCRR and Pythium root rot also thrive in cooler temperatures.

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.

Certain pruning methods increase wounding and leave tissue that is highly susceptible to *Botrytis* (gray mold) infection attached to the stem. Fewer stem lesions develop when petioles are cut or broken close to the stem than when they are removed 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:

- Remove plant debris. Plant debris can serve as a source of ***inoculum*** (any part of a pathogen that is infectious; e.g., bacterial cell, fungal spore, etc.) for future disease outbreaks and can also harbor insects that transmit pathogens. Debris removed from the greenhouse should not be placed outside the greenhouse nearby and should be placed downwind from the greenhouse. It is best if the debris is removed from the site.
- Do not reuse growth containers, such as rockwool slabs and poly bags, or growth medium from which diseased plants were removed. In greenhouses with a nutrient film technique (NFT) system or a modified NFT system, use a suitable disinfectant to disinfest buckets and other materials before planting the next crop. Remember to completely flush the system following treatment to remove disinfectant that could be poisonous to plants.
- Disinfect the greenhouse by spraying all surfaces with a suitable disinfectant. Research has shown that fungal spores may be carried over from season to season in dust on greenhouse support beams.

When producing transplants:

- Use disease-free seeds.
- Use sterile growth media and containers.
- Remove and destroy transplants that do not look normal.

After crop installation:

- Set up a clean-up room where hands and shoes (footbath) can be disinfected and cleaned before entering and after exiting the greenhouse. Use any practice available to prevent introducing pathogens into the greenhouse.
- Restrict the use of tobacco products if ToMV-susceptible varieties are being grown.
- Frequently disinfect tools and other equipment with a suitable disinfectant. Many disinfectants are available. Information on choosing the best disinfectant and how to properly use various disinfectants can be found in publication IS1955 *Choosing a Disinfectant for Tools and Surfaces in Horticultural Operations*.
- 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 the movement of thrips, aphids, and other possible virus-carriers into the greenhouse.
- 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. Destroy diseased plants and plant debris or carry them far enough away downwind from

the greenhouse so that they will not be a source of inoculum to reintroduce the pathogen(s) into the greenhouse.

Chemical Management (Fungicides)

The need for weekly fungicide applications decreases if biological, cultural, and sanitation practices, as previously described, are used. However, it may be necessary to use fungicides as part of an integrated disease management program to successfully manage disease.

When using fungicides, remember: **the label is the law.** You must completely read product labels before use, and you must follow the label. Many fungicides are labeled for use on greenhouse tomatoes. Other fungicides are not prohibited for use on greenhouse tomatoes. The EPA interpretation of fungicide labels indicates that if a product is labeled for use on tomatoes and the product label does not specifically prohibit the use of the product in greenhouses, the product is considered legal to use on tomatoes in the greenhouse.

Please note that product labels change. Some fungicides once labeled for use on greenhouse tomatoes may no longer be legal for use on greenhouse tomatoes. For example, a product purchased some time ago (with the label still attached) may be labeled for use on greenhouse tomatoes and would be legal to use on greenhouse tomatoes, but the same product, purchased recently, may not be labeled for use on greenhouse tomatoes and would not be legal to use on greenhouse tomatoes. This may be due to a change in the makeup of the product, such as the addition of a chemical that is not labeled for use on a food crop.

When using fungicides to manage disease, it is important to rotate (alternate) fungicide groups as part of a resistance management program. Each group of fungicides uses a specific biochemical mode of action to attack a pathogen. The chance of a pathogen becoming resistant to a particular fungicide increases if products with the same mode of action are used repeatedly. For this reason, it is important to alternate fungicide applications with fungicides that have different modes of action. Fungicides are arranged into groups based on their mode of action. These groups, designated by the Fungicide Resistance Action Committee (FRAC), are assigned FRAC codes (e.g., M3, 3, 11). These FRAC codes are normally clearly indicated on the product label. Rotation of fungicides should be based on the FRAC codes (groups) rather than by the product name or the active ingredient of a fungicide since different products may use the same active ingredient or related active ingredients that have the same mode of action.

A list of many of the fungicides labeled for disease management in greenhouse tomatoes is provided in **Table 2**. Information on the efficacy of various products for management of diseases in greenhouse tomatoes is available in the latest edition of the Southeastern U.S. Vegetable Crop Handbook.

Table 2. Biological Products and Fungicides for Disease Management on Greenhouse Tomatoes[1]

Active Ingredient (Product)	FRAC Group[2]	Use Rate	Labeled Diseases/ Pathogens[3]	REI[4] (Days)	PHI[5] (Days)	Comments
acibenzolar-S-methyl (Actigard 50WG)	P	0.33–0.75 oz/acre	Bacterial spot and speck	0.5	14	*Not prohibited for greenhouse use*. Do not make more than eight applications per season. Do not exceed 6 oz per acre per year. Do not apply to stressed plants. Do not make applications on intervals less than 7 days. Use of this product may lead to yield reductions.
aluminum tris (Aliette WDG, Linebacker WDG)	33	2.5–5.0 lb/acre	Damping off (*Pythium* spp.), root rots (*Phytophthora* spp.)	0.5	14	*Not prohibited for greenhouse use. For foliar application*. Do not exceed 20 lb of product per acre per season. Do not apply in less than 10 gal per acre. Phytotoxicity may occur if tank-mixed with copper products, if applied to plants with copper residues, or if mixed with adjuvants. Do not tank-mix with copper products. See label for additional restrictions and application instructions.
azoxystrobin + difenoconazole (Quadris Top)	11 + 9	8 fl oz/acre	Anthracnose (*Colletotrichum* spp.), black mold (*Alternaria alternata*), early blight (*Alternaria solani*), gray leaf spot (*Stemphylium botryosum*), powdery mildew (*Leveillula taurica*), Septoria leaf spot (*Septoria lycopersici*), target spot (*Corynespora cassiicola*)	0.5	0	*Not prohibited for greenhouse use*. Do not use for transplant production. Do not make more than two consecutive applications before switching to a fungicide with a different mode of action. Do not exceed 47 fl oz of product per acre per season. Do not apply until 21 days after transplanting or 35 days after seeding. Do not use with adjuvants or tank mix with any EC product on fresh-market tomatoes. Do not use for transplant production. Plant injury may occur with the use of adjuvants. See label for specifics.
Bacillus subtilis strain QST713 (CEASE, Serenade)	NG	See label	Bacterial speck and spot, Botrytis gray mold, early blight, powdery mildew	See label	See label	**OMRI-listed.** Begin applications prior to disease development, and repeat at 5- to 10-day intervals depending on the formulation. See label for other diseases labeled.
bacteriophage (AgriPhage)	NG	1 pt/50–100 gal water per 9,600 sq ft	Bacterial speck and spot	4 hr	0	***For use as a seedling treatment of greenhouse tomatoes.*** Apply to foliage by fogging or spraying. Do not mix with copper-based fungicides.
Banda de Lupinus albus doce (BLAD) (Fracture)	NG	24.4–36.6 fl oz/acre	Botrytis gray mold, powdery mildew	4 hr	1	*Not prohibited for greenhouse use*. Do not make more than two sequential applications before alternating to a fungicide with a different mode of action.

Table 2. Biological Products and Fungicides for Disease Management on Greenhouse Tomatoes[1]

Active Ingredient (Product)	FRAC Group[2]	Use Rate	Labeled Diseases/ Pathogens[3]	REI[4] (Days)	PHI[5] (Days)	Comments
copper (fixed), including basic copper sulfate, copper oxide, copper hydroxide, copper oxychloride, and copper ions (various[6])	M1	See label	Anthracnose, bacterial speck and spot, early blight, gray leaf mold, late blight, Septoria leaf spot	See label	See label	*Some products labeled for greenhouse use; others not prohibited for greenhouse use.* **Some products are OMRI-listed.** See product labels for complete application instructions and specific disease labels. See product labels for reentry interval requirements. Phytotoxicity may occur under certain environmental conditions or if the spray solution is below a certain pH.
copper sulfate, basic or pentahydrate (Cuprofix Ultra 40 Disperss, Cuproxat Flowable, MasterCop, Phyton 27 AG)	M1	See label	Anthracnose, bacterial speck and spot, early blight, gray leaf mold, late blight, Septoria leaf spot	See label	See label	*Some products labeled for greenhouse use; others not prohibited for greenhouse use.* Under some conditions, phytotoxicity may occur with some products. See label for details on phytotoxicity potential, rate application instructions, and maximum limits and for other labeled diseases. **Cuprofix Ultra 40 Disperss has a 2(ee) label for lower minimum application rates on tomatoes.**
cyazofamid (Ranman 400SC)	21	2.1–2.75 fl oz/acre (late blight) 2.75 fl oz/acre (Phytophthora blight)	Late blight (*Phytophthora infestans*), Phytophthora blight (*P. capsici*)	0.5	0	Do not exceed 16.5 fl oz per acre per year. See label for surfactant recommendations. Alternate applications with fungicides that have a different mode of action. Do not make more than three consecutive applications before switching to products that have a different mode of action for three applications before returning to Ranman 400SC. See label for application instructions specific to target disease. ***Ranman 400SC is allowed for use on fruiting vegetables (tomatoes and bell peppers) in the greenhouse. Ranman is not allowed for use on fruiting vegetables in the greenhouse, EXCEPT for transplant production*** *(see next table entry).*
cyazofamid (Ranman, Ranman 400SC)	21	3 fl oz/100 gal	Damping off (*Pythium* spp.)	0.5	–	***For transplant production only.*** Apply as a soil drench. Do not use a surfactant. One fungicide application can be made to the seedling tray at planting or any time afterward until 1 week before transplanting. ***Ranman is not allowed for use on fruiting vegetables in the greenhouse, EXCEPT for transplant production.***
cymoxanil (Curzate 60DF)	27	3.2–5.0 oz/acre	Late blight (*P. infestans*)	0.5	3	*Not prohibited for greenhouse use.* Use with the labeled rate of a protectant fungicide. Do not exceed 30 oz of product per 12-month period.
cyprodinil + fludioxonil (Switch 62.5WG)	9 + 12	11–14 oz/acre	Early blight (*A. solani*), Botrytis gray mold, powdery mildew (*L. taurica*)	0.5	0	*Not prohibited for greenhouse use.* Do not apply to small tomatoes such as cherry or grape-type tomatoes in the greenhouse. After two applications, alternate with another fungicide with a different mode of action for two applications. See label for application limits.

Table 2. Biological Products and Fungicides for Disease Management on Greenhouse Tomatoes[1]

Active Ingredient (Product)	FRAC Group[2]	Use Rate	Labeled Diseases/ Pathogens[3]	REI[4] (Days)	PHI[5] (Days)	Comments
difenoconazole + cyprodinil (Inspire Super)	3 + 9	16–20 fl oz/acre	Anthracnose (*Colletotrichum* spp.), black mold (*A. alternata*), Botrytis gray mold, early blight (*A. solani*), gray leaf spot (*S. botryosum*), leaf mold (*Fulvia fulva*), powdery mildew (*L. taurica*), Septoria leaf spot, target spot (*C. cassiicola*)	0.5	0	*Not prohibited for greenhouse use.* Do not apply more than 47 fl oz of product per acre per season. Make no more than two consecutive applications per season before alternating with fungicides that have a different mode of action.
etridiazole (Terramaster 4EC)	14	6–7 fl oz/acre	Phytophthora and Pythium root rots	0.5	3	***For application by drip irrigation only.*** Apply as a 0.01% solution (6.5 fl oz/500 gal water) no sooner than 3 weeks after transplanting or a previous application. Do not exceed 27.4 fl oz of product per acre per crop season. Additional indoor restrictions regarding REI are provided on the label. **Product has a Section 24c registration for this use on greenhouse tomatoes in MS.**
famoxadone + cymoxanil (Tanos)	11 + 27	6–8 oz/acre (early blight) 8 oz/acre (other labeled diseases)	Anthracnose (*Colletotrichum* spp.), early blight (*A. solani*), late blight (*P. infestans*), leaf mold (*Cladosporium fulvum*), Septoria leaf spot (*S. lycopersici*), target spot (*C. cassiicola*) ***Suppression:*** Bacterial canker, bacterial speck, bacterial spot, buckeye rot (*Phytophthora* spp.)	0.5	3	*Not prohibited for greenhouse use.* Do not exceed more than 72 oz/acre per crop cycle or 12-month period. Do not make more than one application of product before alternating with a fungicide that has a different mode of action. See label for tank-mixing instructions.
fenhexamid (Decree 50 WDG)	17	1.5 lb/acre (stand-alone) 1.0–1.5 lb/acre (tank-mix)	Botrytis gray mold	0.5	0	Do not make more than two consecutive applications. See label for additional tank-mixing instructions. Do not exceed 6.0 lb product per acre per season for greenhouse production.
hydrogen dioxide + peroxyacetic acid (Oxidate 2.0, ZeroTol 2.0)	NG	32–128 fl oz/100 gal (foliar spray)	Anthracnose, bacterial speck and leaf spot, Botrytis gray mold, Cladosporium mold, early blight (*Alternaria*), *Fusarium*, late blight, *Pythium*, *Rhizoctonia*, powdery mildew	See label	See label	See label for additional information regarding rate usage, including rates specific to nonfoliar applications and other labeled diseases. Do not apply as a foliar spray sooner than at least 24 hrs following application of a metal-based product. Under some conditions, phytotoxicity may result when tank-mixed with metal-based chemicals. **Toxic to bees and other beneficial insects exposed to direct contact on blooming crops.**

Table 2. Biological Products and Fungicides for Disease Management on Greenhouse Tomatoes[1]

Active Ingredient (Product)	FRAC Group[2]	Use Rate	Labeled Diseases/ Pathogens[3]	REI[4] (Days)	PHI[5] (Days)	Comments
mancozeb (various[6])	M3	See label	Anthracnose, bacterial speck and spot, early blight, gray leaf spot, late blight, leaf mold, Septoria leaf spot	See label	See label	*Some products labeled for greenhouse use; others not prohibited for greenhouse use.* See product label for complete application instructions.
mancozeb + copper (ManKocide)	M3 + M1	1.7 lb/acre (processing) 1–3 lb/acre (fresh market)	Anthracnose, bacterial speck and spot, early blight, gray leaf spot, late blight, leaf mold, Septoria leaf spot	2	5	*Not prohibited for greenhouse use.* Do not exceed 58 lb product per acre per crop east of the Mississippi River or 42.66 lb product per acre per crop west of the Mississippi River. Phytotoxicity may occur when spray solution has a pH of less than 6.5 or when certain environmental conditions occur.
mancozeb + zoxamide (Gavel 75DF)	M3 + 22	1.5– 2.0 lb/acre	Anthracnose, bacterial speck and spot, buckeye rot, early blight, gray leaf spot, late blight, leaf mold, Septoria leaf spot	2	5	*Not prohibited for greenhouse use.* Do not exceed 8 lb per acre per season west of the Mississippi River or 16 lb per acre per season east of the Mississippi River. For bacterial speck and spot, apply the full rate of product in a tank mix with a full rate of a fixed copper. See label for other application limits. **Product has a 2ee registration for anthracnose.**
mandipropamid (Micora)	40	5.5–8.0 fl oz/acre	Late blight (*P. infestans*)	4 hr	–	***For tomatoes grown for transplants and retail sale to consumers only.*** Do not make more than two applications per crop. Do not make more than two consecutive applications before switching to a fungicide from a different FRAC group.
mandipropamid + difenoconazole (Revus Top)	3 + 40	5.5–7.0 fl oz/acre	Anthracnose (*Colletotrichum* spp.), black mold (*A. alternata*), early blight, (*A. solani*), gray leaf spot (*S. botryosum*), late blight (*P. infestans*), leaf mold (*F. fulva*), powdery mildew (*L. taurica*), Septoria leaf spot, target spot (*C. cassiicola*)	0.5	1	*Not prohibited for greenhouse use.* Do not make more than two consecutive applications per season before alternating with fungicides that have a different mode of action. Do not exceed 28 fl oz of product per acre per season.
mefenoxam + mancozeb (Ridomil Gold MZ WG)	4 + M3	2.5 lb/acre	Late blight (*P. infestans*)	2	5	*Not prohibited for greenhouse use.* Do not exceed 7.5 lb product per acre per crop per season. Do not exceed three applications per season. Apply a protectant fungicide in between applications of product. See label for other restrictions.
myclobutanil (Rally 40WSP)	3	2.5–4 oz/acre	Powdery mildew (*Leveillula* spp.), Southern blight	2	0	*Not prohibited for greenhouse use.* Do not exceed 1.25 lb product per acre per crop. Do not exceed 21 days between applications.
neem oil (Triact 70)	NG	See label	*Botrytis*, powdery mildew	See label	See label	**OMRI-listed.** Apply to just before runoff. See label for other diseases labeled. **Toxic to bees.**

Table 2. Biological Products and Fungicides for Disease Management on Greenhouse Tomatoes[1]

Active Ingredient (Product)	FRAC Group[2]	Use Rate	Labeled Diseases/ Pathogens[3]	REI[4] (Days)	PHI[5] (Days)	Comments
pentachloronitrobenzene, PCNB (Blocker 4F)	14	4.5–7.5 pt/100 gal	Southern blight (*Sclerotium rolfsii*)	0.5	–	*Not prohibited for greenhouse use.* ***For use as a transplant solution.*** Product applicators, loaders, and mixers cannot handle amounts exceeding 0.42 gal product per day. Use 0.5 pt solution per plant. See label for limits on amount of active ingredient applied per season.
penthiopyrad (Fontelis)	7	0.5–0.75 fl oz/gal per 1,360 sq ft	Alternaria blights and leaf spots, black mold (*A. alternata*), early blight, Botrytis gray mold, powdery mildew (*L. taurica*), basal stem rot (*S. rolfsii*), Septoria leaf spot, target spot (*C. cassiicola*) ***Suppression:*** Anthracnose	0.5	0	Do not exceed 72 fl oz of product per year. Do not make more than two consecutive applications per season before alternating with fungicides that have a different mode of action. See label for specific instructions for basal stem rot.
polyoxin D zinc salt (Affirm WDG)	19	6.2 oz/acre	Botrytis rot, early blight, powdery mildew (*L. taurica*) ***Suppression:*** Anthracnose	4 hr	0	Do not exceed five applications per season. Alternate with fungicides that have a different mode of action.
potassium bicarbonate (Milstop)	NG	1.25–5.0 lb/100 gal	Alternaria leaf spot, anthracnose, *Botrytis*, Cercospora leaf spot, powdery mildew, Septoria leaf spot	1 hr	0	**OMRI-listed.** Do not exceed 0.5 lb of product per 4,350 sq ft or 1.15 lb product per 10,000 sq ft per application. Do not store unused spray solution. See label for additional diseases labeled.
potassium phosphite + chlorothalonil (Catamaran)	33 + M5	4.5–5.5 pt/acre (foliage diseases) 7 pt/acre (fruit diseases)	***On foliage:*** Early blight, gray leaf mold, gray leaf spot, late blight, Septoria leaf spot, target spot ***On fruit:*** Anthracnose, Alternaria fruit rot, *Botrytis*, late blight rot, Rhizoctonia rot	0.5	0	*Not prohibited for greenhouse use.* Do not exceed 50 pt per acre per season. Phytotoxicity potential. Do not combine with other pesticides, surfactants, or fertilizers. May be applied on the day of harvest.

Table 2. Biological Products and Fungicides for Disease Management on Greenhouse Tomatoes[1]

Active Ingredient (Product)	FRAC Group[2]	Use Rate	Labeled Diseases/ Pathogens[3]	REI[4] (Days)	PHI[5] (Days)	Comments
promocarb hydrochloride (Previcur Flex)	28	See label	Damping off and root rots (*Phytophthora* spp., *Pythium* spp.)	0.5	5	***For use through a drip system or as a soil drench.*** Do not apply more than four applications of product after transplanting per crop cycle. Do not mix with other products. Phytotoxicity may occur if applied to dry growing media.
		See label	Damping off and root rots (*Phytophthora* spp., *Pythium* spp.)	0.5	–	***For preseeding and/or seedling treatment (before transplanting).*** Do not mix with other products. See label for specific use directions. Phytotoxicity may occur if applied to dry growing media.
pyraclostrobin + boscalid (Pageant Intrinsic)	7 + 11	23 oz/acre	Botrytis gray mold	0.5	0	Do not tank mix with adjuvants or other agricultural products. Do not exceed 69 oz/acre of product per crop cycle. Do not make more than one application of product before switching to a fungicide with a different mode of action.
		See label	Crown and basal rot (*Fusarium* spp., *Rhizoctonia solani*, *Sclerotinia* spp.), damping off (*Pythium* spp., *Rhizoctonia* spp.), downy mildew (*Peronospora* spp., *Plasmopara* spp.), spots and blights (*Alternaria* spp., *Cercospora* spp., *Phoma* spp., *Septoria* spp.), Phytophthora blight, powdery mildew (*Leveillula* spp. and *Oidiopsis* spp.), rots and blights (*Botrytis)*	0.5	–	***For use on transplants intended for the home consumer market. Do not use product for transplants that are intended for agricultural production fields.*** Do not tank mix with adjuvants or other agricultural products. See label for application rates specific to a particular disease and for application limits (growing cycle, consecutive crops, production structure).
pyrimethanil (Scala SC)	9	7 fl oz/acre	Botrytis gray mold, early blight	0.5	1	Plant injury may occur in nonventilated houses; ventilate for at least 2 hr after application. Use only in a tank mix with another fungicide for early blight. Do not exceed 35 fl oz per acre per crop.
Reynoutria sachalinensis extract (Regalia Biofungicide)	P5	See label	Botrytis gray mold, bacterial speck and spot, early blight, powdery mildew	See label	See label	*Not prohibited for greenhouse use*. See label for application instructions specific to use. See label for additional labeled diseases.
Streptomyces griseoviridis strain K61 (Mycostop Biofungicide)	NG	See label	***Suppression:*** Pythium, Rhizoctonia, and Phytophthora root rots	4 hr	See label	*Not prohibited for greenhouse use*. **OMRI-listed.** See label for application instructions specific to use and other diseases labeled.

Table 2. Biological Products and Fungicides for Disease Management on Greenhouse Tomatoes[1]

Active Ingredient (Product)	FRAC Group[2]	Use Rate	Labeled Diseases/ Pathogens[3]	REI[4] (Days)	PHI[5] (Days)	Comments
streptomycin sulfate (Agri-Mycin 17, Ag Streptomycin, Firewall 17 WP, Firewall 50 WP, Harbour)	25	See label	Bacterial canker, speck, and/or spot	0.5	–	***For transplant production only.*** Begin applications at the first true leaf stage. Repeat at 4- to 5-day intervals until transplanting in the field. Check product labels for specific diseases labeled and application rates. Firewall 50 WP has a maximum of six applications per year.
sulfur (Microthiol Disperss, Sulfur 6L)	M2	5–20 lb/acre (Microthiol Disperss)	Powdery mildew	1	See label	*Not prohibited for greenhouse use.* **Microthiol Disperss is OMRI-listed.** Plant injury may occur under certain environmental conditions. Do not apply when temperatures are high as foliage burn may occur. Do not apply within 2 weeks of an application of an oil- or petroleum-based product (see product label for exceptions). See product label for additional restrictions and application instructions.
		4–10 2/3 pt/acre (Sulfur 6L)		1	See label	
triflumizole (Terraguard SC)	3	2–4 fl oz/100 gal	Powdery mildew	0.5	1	***For use only as a foliar spray. For use only in commercial greenhouse production.*** Can be used on greenhouse transplants. Do not exceed 40 fl oz of product per acre per cropping system. See label for additional application instructions. **Products not registered for use in all states.**
zinc dimethyldithio-carbamate (Ziram 76DF)	M3	3–4 lb/acre	Anthracnose, early blight, Septoria leaf spot	2	7	*Not prohibited for greenhouse use.* Do not use on cherry tomatoes. Do not exceed 23.7 lb per acre per crop cycle. May be mixed with copper fungicides.

Table 2 is modified from Table 3-46, Greenhouse Disease Control for Various Vegetable Crops, by R. A. Melanson, F. Louws, M. L. Lewis Ivey, and A. Keinath, and Table 3-47, Biorational and Biological Products for Greenhouse Vegetable Disease Management, by R. A. Melanson, F. Louws, and M. L. Lewis Ivey, in the 2017 Southeastern U.S. Vegetable Crop Handbook. Information on the efficacy of various products for management of diseases in greenhouse tomatoes is available in the the Southeastern U.S. Vegetable Crop Handbook.

[1]Products may be used in a greenhouse if the product label specifically allows for greenhouse use. Products that do not specifically prohibit greenhouse use may be used in the greenhouse as long as the product is labeled for the intended crop and the label instructions are followed. In these instances, the phrase "not prohibited for greenhouse use" is included in the comments. Product labels change; always check the product label before use, and read and follow all label instructions. The label is the law. Products included in this table were, at the time of its creation, labeled for use in Mississippi. Several products with the same active ingredient as those listed in this table are not labeled for use in Mississippi and, therefore, were not included in this table.

[2]FRAC = Fungicide Resistance Action Committee. The FRAC groups fungicides based on the mode of action of the active ingredient. NG = not grouped. Fungicides in the "M" categories have multiple modes of action.

[3]The name of the pathogen that causes leaf mold has changed over the years. Former names of *Passalora fulva* include *Fulvia fulva* and *Cladosporium fulvum*. These names, as well as Cladosporium leaf mold, may still appear on various fungicide labels.

[4]REI = restricted entry interval. The REI is the time that must pass after product application before workers may enter the treated area without personal protective equipment (PPE).

[5]PHI = pre-harvest interval. The PHI is the least amount of time that must pass between the last application of the product and harvest.

[6]Copper products labeled for use on tomatoes in the greenhouse (GH) or not prohibited for use on tomatoes in the greenhouse include: Badge SC (GH), Badge X2 (GH), Camelot-O (GH), Champ Dry Prill (GH), Champ Formula 2 Flowable (GH), Champ WG (GH), ChampION++ (GH), Kocide 2000 (GH), Kocide 3000 (GH), Nordox 75 WG (GH), Nu-Cop 50 DF (GH), and Stretch (NP). Mancozeb products labeled for use on tomatoes in the greenhouse (GH) or not prohibited for use on tomatoes in the greenhouse (NP) include: Dithane F-45 Rainshield (NP), Dithane M45 (GH), Fortuna 75 WDG (GH), Koverall (GH), Manzate Flowable (NP), Manzate Max (NP), Manzate Pro-Stick (NP), Penncozeb 75DF (NP), Penncozeb 80WP (NP), and Roper DF Rainshield (GH). These listed mancozeb products all have a 5-day PHI and a 2-day REI.

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.

Additional Resources

Taking Photos of Plant Disease Problems (P3022)
http://extension.msstate.edu/publications/publications/taking-photos-plant-disease-problems

How to Collect and Package Plant Disease Specimens for Diagnosis (M1562)
http://extension.msstate.edu/publications/miscellaneous/how-collect-and-package-plant-disease-specimens-for-diagnosis

Plant Disease Sample Submission Form (F1139)
http://extension.msstate.edu/publications/forms/plant-disease-sample-submission-form

Organic IPM Vegetable Guide (P2036)
http://extension.msstate.edu/publications/publications/organic-vegetable-ipm-guide

Organic Materials Review Institute website (www.omri.org)

Choosing a Disinfectant for Tools and Surfaces in Horticultural Operations (IS1955)
http://extension.msstate.edu/publications/information-sheets/choosing-disinfectant-for-tools-and-surfaces-horticultural

Southeastern U.S. Vegetable Crop Handbook
available online (http://www.thepacker.com/guides/Pest-production-guides) or by contacting your local county Extension office

Tomato Troubles: Common Problems with Tomatoes (P2975)
http://extension.msstate.edu/publications/publications/tomato-troubles-common-problems-tomatoes

Greenhouse Tomato Handbook (P1828)
http://extension.msstate.edu/publications/publications/greenhouse-tomato-handbook

Greenhouse Tomato Growers' Glossary (P2364)
http://extension.msstate.edu/publications/publications/greenhouse-tomato-growers-glossary

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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