Mississippi State University Extension Service

Greenhouse Tomatoes

Pest Management in Mississippi

Mississippi is one of the leading states in greenhouse tomato production. Growers have found a ready market as more consumers discover that taste and quality of greenhouse tomatoes rival fruit produced in the home garden.

Although market demand for greenhouse tomatoes is expected to continue, a supply of high-quality fruit required by expanding markets depends on the ability of growers to avoid production problems caused by greenhouse pests. In Mississippi and other Southeastern states, insects are constant threats, and high, relative humidity favors development of disease problems. Unless growers follow a sound approach in handling pest problems, insects and diseases can rapidly destroy a crop.

Growers who successfully combat greenhouse tomato pests commonly rely on integrated pest management (IPM). IPM allows growers to use a combination of biological, cultural, and chemical techniques to suppress pest populations. An integrated approach encourages preventive measures to avoid diseases that are likely to attack the crop, crop monitoring to allow early detection of manageable levels of insects and diseases, and other means other than strict reliance on pesticides. Growers who attempt to initiate a pest management program after insects and diseases have become widespread generally face an uphill battle with predictable results.

Insect Management

The most common insect pests of greenhouse tomatoes are aphids, armyworms, cabbage loopers, leaf miners, tomato fruitworms, pinworms, and whiteflies. Under hot, dry conditions, spider mites can become a problem. Slugs can also become a problem under warm, moist conditions. Insects generally migrate to houses in the fall when field populations are high and before covers are added or openings are screened or closed. Some pests are brought in on new plants bought or exchanged with other growers. Some may come in with soil, mulching materials, or equipment from outdoors. Insects have the ability to reproduce rapidly and cause extensive damage under greenhouse conditions, which are void of natural forces (predators/parasites) that often keep insects under control. Greenhouse growers must use every available tactic and scheme to maintain an environment in the greenhouse where a marketable and high-quality product can be grown.

It is important to prevent insects from entering greenhouses, and this can be accomplished by using screens and proper installation of exhaust fans that are fully covered. If at all possible, eliminate insect pests that are within 100 feet of greenhouses to prevent their migration into houses. This may be done with recommended insecticides, weed control, and/or cultural practices. Always use sound cultural practices, good sanitation practices, and insect-free transplants to help prevent insect establishment.

Early detection and diagnosis of insect problems are keys to successful control. Inspect greenhouse tomatoes once or twice a week for insects. Thoroughly examine plants' upper and lower leaf surfaces, terminal buds, blooms, fruit, and stems. In order to obtain good control of insects, it is important to identify them correctly and to apply the recommended insecticide in a timely manner with good coverage. The ultimate goal in greenhouse production is a high-quality crop that will produce its maximum potential yield.

Many chemicals legally labeled for use on field-grown tomatoes may not be labeled for greenhouse use. Growers must use this small number of chemicals properly and wisely in order to keep them registered. In some cases, chemicals are the only effective means of insect control.

Pesticide Safety

Pesticide safety is extremely important, particularly in greenhouse tomato production. Remember, the label is the law; therefore, growers must read and follow the pesticide label. When applying pesticides, applicators must wear protective clothing and dispose of empty pesticide containers in the correct manner.

Storage of Pesticides

Keep pesticides in an area that is inaccessible to children, adults who are unfamiliar with pesticides, and animals. Store all pesticides under lock and key. Do not store with or near feed, seed, clothing, or other articles. Storage areas should be well-lighted ventilated places where temperatures will not go below freezing. Facilities should be fire-resistant and have an exhaust fan. Place warning signs on all entrances and keep doors locked.

Keep products stored in their original containers, and mark the month and year of purchase on all packages to determine age of products. Keep an up-to-date inventory of pesticide products available.

Biological Control

Biological control is only one phase of the system used to manage pest problems in an Integrated Pest Management (IPM) program. Other phases include use of resistant varieties, temperature control, humidity control, barriers, monitoring devices, and the use of insecticides, which are used as the last resort.

Natural enemies, including predators and parasites, feed on most insect pests occurring in greenhouses. The use of beneficials to control pests in greenhouses can be a viable alternative to insecticide use. Keep in mind, regardless of the specific biological control method used, there will be a limited number of pests surviving in your crop.

The ladybug is probably the most widely known beneficial insect. They are almost everywhere, and most of them are predaceous. They feed primarily on aphids, but will feed on any soft-bodied insect. Before releasing ladybugs, mist your plants first because the ladybugs may be thirsty. Approximately 1,000 ladybugs should be enough to cover a home greenhouse; or use 1 gallon of ladybugs per acre. They perform best when released in mid- to late-afternoon.

The lacewing is another popular beneficial insect. Lacewings prey on eggs and many soft-bodied insects, such as scales, aphids, and mealybugs. Lacewing eggs may be applied around insect-infested plants. For best control, apply at least 1 lacewing per 10 aphids. It may be necessary to make two or three releases, two weeks apart.

Parasitic wasps of the species Encarsia formosa are tiny wasps that lay eggs into greenhouse whitefly larvae. It is best to apply the parasite soon after transplanting at the rate of at least one to two per square foot. It usually takes two releases, two weeks apart, but may require additional releases if whitefly infestations flare up. In order to properly time wasp release, use yellow sticky traps in conjunction with this wasp. Proper timing and early introduction of wasps are essential for whitefly control. Traps come in cards or ribbons and are coated with a specially formulated sticky material. Always place traps at plant level or lower. Traps are used as an indicator that whiteflies are present. Release parasitic wasps when numbers of whiteflies are low, less than one adult per upper leaf. Keep in mind, Encarsia can provide effective control of greenhouse whitefly but has not been effective against sweetpotato whitefly; therefore, it is important to know which whitefly is present before attempting to use Encarsia.

The predators *Amblyseius mckenziei* and *A. cucumeris* are predatory mites used to help control thrips. These predators feed on immature thrips. Releases of one predator mite per square foot, two weeks after transplanting, and repeating applications every month during warm, dry weather will give best results. Use yellow, sticky traps also in conjunction with the release of this predatory mite. Many adult thrips are attracted to the traps and are captured, thus reducing the number of eggs laid.

There are many other beneficial predators: ants, assassin bugs, damsel bugs, ground beetles, syrphid flies, praying mantis, predaceous mites and wasps, and spiders. The conservation of these natural enemies is a useful control strategy for greenhouse owners. Conservation involves a knowledge of insect biology, maintenance of insect habitats, and judicious use of insecticides.

There is a material called Insect Barrier, which may be placed over intake vents and other openings to your greenhouse. This barrier reduces the number of unwanted small insects (e.g., whitefly, thrips) that enter into your greenhouse. Everything flying near the vents is pulled in when the exhaust fans are running.

Major Insect Pests

Aphids

Aphids (plant lice) are small, soft-bodied insects that vary in color from light green to yellow. They suck plant juices, causing leaves to curl and turn yellow. They may also inject poisonous saliva or disease-causing organisms during feeding. They may cause a failure of bloom set in some vegetable crops. These insects secrete “honeydew,” which can support the growth of sooty mold fungus. This sticky substance can further reduce plant and fruit quality.

Armyworms

Armyworms come in various species. Generally the fall armyworm is the one attacking tomatoes. They vary in color from light tan or green to nearly black. They have a prominent inverted Y on the front of their heads. Their bodies have a greasy appearance and may be up to 2 inches long. They are primarily foliage feeders.

Cabbage Loopers

Loopers are pale-green measuring worms with only two pairs of prolegs. They have light-colored stripes down their backs and are up to 1 inch long. They are one of the more difficult caterpillars to control.

Fruitworms

Fruitworms may be difficult for some growers to identify. The tomato fruitworm is the same insect as the cotton bollworm, corn earworm, or soybean podworm and measures up to 1 1/2 to 2 inches long. They are greenish or brownish striped caterpillars. The tomato fruitworm feeds on blooms as well as the fruits of tomatoes, from the time they are formed until they are ripe. If not controlled, this caterpillar can contaminate or destroy up to 50 to 80 percent of the fruit.

Fungus Gnats

Fungus gnat larvae are up to 5.5 mm in length and clear with a black head capsule. The adults are less than one-eighth inch long with beaded antennae and a distinctive wing with a Y-shaped vein that is held away from the body when resting. They generally are most abundant in

the winter and spring. Adults and larvae prefer moist, shady areas. Adults live about 1 week, during which time each female deposits 100 to 150 eggs in strings of 3 to 40 in the top of the soil near plant stems. They hatch within 4 days, and larvae begin feeding on root hairs and roots, eventually working into the stem. Larvae mature in about 2 weeks, then construct a pupal case and remain there about 3 1/2 days before emerging as adults. Several generations usually occur.

Leaf Miners

Leaf miners (serpentine and vegetable leaf miners) feed on a variety of vegetable crops including tomatoes. Plants fed upon by leaf miners will have disfigured and damaged leaves caused by the larva (maggot) stage of this insect. Their feedings result in whitish blotches or blasted areas, or, in the case of the serpentine leaf miner, slender, white winding trails through the interior of the leaf. The mining areas serve as points of entrance for disease and decay.

The leaf-mining stage may last up to 12 days, with less time during the warm summer months. A new generation is produced approximately every 23 days. Generally, there are at least five generations, with more under greenhouse conditions.

Adult leaf miners resemble fruit flies. They may be seen readily resting on the upper surface of leaves. Yellowish maggots emerge from eggs laid in the leaves; they begin to enlarge their tunnels as they feed between leaf surfaces. Larvae then pupate into round yellowish-orange, bullet-shaped pupae that may be seen on leaf surfaces or on the ground underneath plants. Sanitation is helpful in controlling them. It also is helpful to remove and destroy lower infested leaves. Plastic sheets placed on the potting surface help reduce its population.

Pinworms

Pinworms are tiny caterpillars (1/4 inch full grown) yellowish, gray, or green with purple spots and a brown head. They bore holes into buds and ripening fruit near the stem. Adults are small, gray moths about 1/4 inch long and generally are active at dusk.

Eggs are small and usually laid on lower surfaces of leaves. Larvae also feed as leaf miners and may cause white blotches on leaves that are folded together or on leaves that are held together by webs.

Life cycle from egg to adult varies, but averages about 30 days during the summer and 40 to 55 days during the winter.

Slugs

Slugs are soft-bodied, grayish or mottled, slimy creatures measuring up to 4 inches long. They are unrelated to insects, and their bodies are covered by a thick mucous membrane. They can become serious pests in greenhouses.

Slugs feed on molds, decaying organic matter, and the foliage of plants. They must have a large amount of moisture to survive, and they prefer darkness Ideal habitats include under boards, trash and other debris, and in crevices. In greenhouses, rotting boards, bedding, pots, and debris beneath the benches usually harbor these pests.

They are active at night and leave a silver-colored, slimy trail wherever they travel. These trails can be seen on foundation walls, floors, walks, and plant leaves.

Slugs often can be controlled by eliminating their hiding places, e.g., remove rotting boards and debris left on the ground. In greenhouses, keep the area under the benches free of trash.

Spider Mites

Spider mites are not insects but tiny, almost microscopic pests that feed on the undersides of leaves. They remove the sap, causing the leaves to become discolored. Where populations are heavy, they can cause leaves to drop off. They vary in color from light green to red.Two-spotted mites are the most difficult to control.

Mites may reach damaging populations. Close examination of the undersides of leaves with a hand lens reveals a fine webbing of silk. Mites may be found in this webbing or on the leaf surface. In severe cases, mites may be found on the upper surface of the leaves.

Control of spider mites usually requires multiple applications of a miticide at weekly intervals.

Whiteflies

Whiteflies are a common and persistent problem of greenhouse tomatoes. They are related to aphids (plant lice) and are not true flies.

Adults are about 1/16 inch long, white in color, and have four powdery wings. Feeding and egg laying generally occur on the undersides of leaves. Nearly 150 or more eggs are laid by each adult female. Under greenhouse conditions, eggs hatch in about 10 days into tiny, white, oval “crawlers.” These move about on the undersides of leaves for 1 to 2 days searching for a suitable feeding site. On finding a site, the crawlers lose their legs and stop all movement for the remainder of the nymph’s development. Nymphs go through three instars and a pupa stage before reaching adulthood. Full development generally takes from 25 to 30 days in greenhouses. Adults may live up to 30 days.

Adult and immature (nymph) stages suck plant fluids from plant foliage with their piercing-sucking mouthparts. Further injury may result from whiteflies secreting a sticky “honeydew” that adheres to foliage and fruit. This can result in a black sooty fungus (mold) growing on the honeydew , and this can interfere with leaf respiration.

Whiteflies can reduce yields of greenhouse-grown tomatoes. To prevent yield loss, these insects must be controlled or kept to a low level during the growth period.

Generally, it is better to spray when the temperature is 70 to 80 degrees Fahrenheit. Spray applications every second day may be needed for 21 days in order to break its life cycle. Alternate insecticides if necessary.

Whitefly eggs and pupae generally are not controlled with insecticides. Therefore, you must carry on a regular control program or you will be overrun with whiteflies. Correct timing and thorough coverage of insecticide are musts if whiteflies are to be kept under control in greenhouses.

Recommendations for Insect Control on Greenhouse Tomatoes

Insect	Insecticide and formulation	Amount of formulation	Minimum interval between last application and harvest	Precautions, remarks
Aphids	dichlorvos (DDVP) 10A	Follow label directions	1 day	
	endosulfan (Thiodan, Phaser)			Make sure the greenhouse is tightly close when using aerosols; then applying the air above the plants. The optimum temperature before application is 70-80 degrees F. Keep greenhouse closed for at least 2 hours. Highly toxic—use with caution. Ventilate before reentry. Do not exceed 5 applications of endosulfan/year.
	10A	1 lb/50,000 cu ft	15 hours	
	50 WP	1 lb/100 gal water	2 days	
	3 EC	1 qt/100 gal water	2 days	
	malathion (various)			Apply as needed in the closed greenhouse in the air above the plants. Spray when the temperature is 70-85 degrees F. Keep ventilator closed for 2 hours. Hazardous to honey bees.
	10A	1 lb/50,000 cu ft	15 hours	
	57 EC	1 qt/100 gal water	1 days	
	25 WP	4 lb/100 gal water	1 days	
	Insecticidal soap M-pede 49 EC	2 tbsp/gal water	0 day	May be used alone or tank mixed with a companion insecticide. Read labels.
	Pyrelli EC	1 to 2pt/100 gal water	0 day	Full coverage spray is necessary.
Armyworms	endosulfan (Thiodan, Phaser)			
	10A	1 lb/50,000 cu ft	15 hours	See remarks under aphids.
	50 W	2 lb/100 gal water	2 days	Do not exceed 5 applications of endosulfan per year.
	3 EC	1 qt/100 gal water	2 days	
	malathion (various)			See instructions for aphids; hazardous to honey bees.
	10A	1 lb/50,000 cu ft	15 hours	
	57 EC	1 qt/100 gal water	1 day	
	25 WP	4 lb/100 gal water	1 day	
	Javelin WG	1 lb/100 gal water	0 day	Full coverage spray is necessary.
	Azatin EC	10 to 16oz/ 100 gal water	12 hours	Foliar application to larvae.

Recommendations for Insect Control on Greenhouse Tomatoes (continued)

Insect	Insecticide and formulation	Amount of formulation	Minimum interval between last application and harvest	Precautions, remarks
Cabbage loopers	*Bacillus thuringiensis* (various)	1/2 to 1 lb or 2 to 3 pt/100 gal water	0 day	Full coverage spray is necessary.
	Javelin WG	1/2 lb/100 gal water	0 day	Full coverage spray is necessary.
	Azatin EC	10 to 16oz/ 100 gal water	12 hours	Foliar application to larvae.
Climbing cutworms		See armyworms		
Fungus gnats	Gnatrol (B.t.)	4 to 8 tbsp/gal water	0 day	Apply as a soil drench.Controls only larvae. Second and third applications may be necessary at 7- day intervals to help avoid reinfestations. Clean cultural practices and lack of excessive watering many times will prevent fungus gnat infestations.
	malathion (various)			For control of adults only. See rates and remarks under aphids.
	Azatin EC	8 oz/100 gal water	12 hours	Apply as soil drench for maggot control.
Leaf miners	malathion (various) 10 A	1 lb/50,000 cu ft	15 hours	See remarks under aphids.
	Azatin EC	10 to 16oz/ 100 gal water	12 hours	Use a foliar spray for control of larvae. When pest populations are high, use the higher rate. For best results, use a spreader-sticker.Full coverage is necessary for effective control.
Millipedes and crickets	malathion (various) 5 D	Follow label directions		Apply to soil at base of plants. Do not contaminate fruit.
Slugs	metaldehyde bait	Follow label directions		Apply to soil surface around plants. Do not contaminate fruit.
Spider mites	malathion 57 EC	1 to 2pt/ 100 gal water	1 day	Spray plants thoroughly.
	Insecticidal soap (M-pede) 49 EC	2 tbsp/gal water	0 day	May be used alone or tank mixed with a companion insecticide. Read labels.
Thrips	methoxychlor (Mariate) 10 A	0.5 lb/50,000 cu ft	7 days	
	Azatin EC	10 to 16oz/ 100gal water	12 hours	Suppression of larvae and adult feeding deterrence.
	malathion 57 EC	1 1/2 to 2pt/ 100 gal water	1 day	Spray plants thoroughly.

Recommendations for Insect Control on Greenhouse Tomatoes (continued)

Insect	Insecticide and formulation	Amount of formulation	Minimum interval between last application and harvest	Precautions, remarks
Tomato fruitworms		See armyworms		
Tomato pinworms	*Bacillus thuringiensis* (various)	See cabbage loopers	0 day	Second and third applications may be necessary at 7- day intervals to help avoid reinfestations.
	+	See armyworms	2 day	
	endosulfan (Thiodan, Phaser) or malathion	See armyworms	1 day	
Whiteflies	dichlorvos (DDVP, Vapona)	Follow label directions	24 hours	Sanitation, use of yellow sticky traps, and *Encarsia* parasites are encouraged.
	endosulfan (Thiodan, Phaser)			
	50 WP	1 lb/100 gal water	2 days	Do not exceed 5 applications per year.
	3 EC	2/3 qt/100 gal water	2 days	
	malathion (various)			
	10 A	1 lb/50,000 cu ft	15 hours	Apply as needed in the closed greenhouse in the air above the plants. Spray when temperature is 70-80 °F. Sprays every second day may be needed. Keep ventilator closed for 2 hours. Hazardous to honey bees.
	57 EC	1 qt/100 gal water	1 days	
	25 WP	4 lb/100 gal water	1 days	
	Insecticidal soap (M-pede) 49 EC	2 tbsp/gal water	0 day	May be used alone or tank mixed with a companion insecticide. Read labels.
	Pyrelli EC (pyrethrin + rotenone + cube resin)	2 tsp/gal water	0 day	Read and follow label directions.
	Pyronone (pyrethrin + PB)	12 oz/20 gal water	0 day	May be used alone or tank mixed with a companion insecticide. Read label.
	Azatin EC	10 to 16oz/ 100 gal water	12 hours	Use as a foliar spray for control of larvae and pupae. When pest populations are high, use the higher Azatin EC label rates. For best results, use a spreader-sticker. Full coverage is necessary for effective control.

NOTE: In many instances, insecticide recommendations for greenhouse use are given on the basis of 100 gallons of total spray, but only 1 gallon is needed. The following is a general rule to use to prepare 1 gallon of spray. For each 1 pound of wettable powder recommended per 100 gallons of water, use 1 level tablespoonful for 1gallon. For each pint of liquid recommended per 100 gallons of water, use 1 teaspoonful for 1 gallon. Abbreviations for chemical formulations: A = Aerosol; D = Dust; EC = Emulsifiable Concentrate; WP = Wettable Powder; WG = Wettable Granular.

Disease Identification and Management

To develop a greenhouse tomato disease pest management program, you must know the diseases that affect the crop and the conditions under which they are likely to cause problems.

Diseases that occur on greenhouse tomatoes exhibit symptoms on roots, stems, leaves, and fruit. While some symptoms are common to several diseases, it is generally possible to identify the more common fungal and bacterial disorders. However, some virus diseases may be more difficult to identify. Should you experience difficulty, bring specimens to your local Extension office, or mail to a plant disease diagnostic lab. Before sending a sample for analysis, check with your county Extension agent about the correct method of sample collection and packaging. Include pertinent information, e.g., recent application of pesticides, periods of extreme humidity, and other information that could be useful for an accurate diagnosis.

The "key symptom" approach to disease identification works well for most growers. Do not try to remember all symptoms that could be produced by a given disease. Scout plants for those diagnostic features characteristic for a given disease; this improves the accuracy of disease determinations and management steps necessary for its control. "Key symptoms" described for each of the following diseases should help identify diseases that could occur in the crop.

Disease Identification

Fungus Diseases

Botrytis gray mold (*Botrytis cinerea*) is probably the most common and troublesome disease in greenhouse tomatoes, since resistant varieties are not available and the fungus is present in all greenhouses. Infection by the gray mold fungus occurs when the relative humidity is high (90 percent or higher). All plant parts are susceptible to invasion. Generally, plant susceptibility increases during fruit bearing. **Key symptom:** Look for light-tan or gray spots on infected leaves. These areas become covered by a brown or gray fuzzy mass of fungus growth, and the leaf collapses and withers.

Other sites of infection include dying flowers and the calyx area of fruit. From this latter site, infection proceeds into fruit that quickly becomes water-soaked and soft When infected tissue is examined under a hand lens, spore-bearing structures resembling bunches of grapes are discernible. Spores are easily detached and serve as sources of inoculum for stem infection. Since the causal fungus does not actively attack healthy tissue, stem invasion occurs through branch stubs resulting from pruning or other sites along the stem where there is an injury.The tan cankers that form along the stem may be extensive and frequently are responsible for premature plant death. Under humid conditions, distinctive masses of fungus growth are formed on canker surfaces.

Leaf mold (*Fulvia fulva = Cladosporium fulvum*) was a common and severe problem in the early 1970's, because resistant varieties were not generally available. Today, most modern varieties have complete resistance (C5) to all races of the leaf mold fungus (refer to section on **Disease Management**). Varieties with incomplete resistance (C2) frequently are affected by leaf mold under humid conditions. Scout these varieties frequently for early symptoms of this disease. Infection of susceptible tissue by the leaf mold fungus occurs when relative humidity remains high (90 percent or higher) for several hours. This disease is favored by the same conditions that encourage gray mold development. Leaf mold symptoms begin on lower, senescent leaves, but appear progressively on younger foliage. **Key symptom:** Look for pale-green or yellowish areas with irregular margins on upper leaf surfaces. Beneath the yellow spots, areas of olive-green velvet growth are visible. Infected leaves become yellowish brown and drop prematurely. Defoliation progresses up the plant.

Early blight (*Alternaria solani*) occasionally causes problems in greenhouse tomatoes. Symptoms appear on leaves, stems, and fruit. **Key symptom:** Look for characteristic circular brown leaf spots, up to 1/2 inch in diameter. Spots contain dark concentric rings that take on a "target board" appearance.

Powdery mildew (*Erysiphye sp.*) is not a widespread greenhouse tomato problem in Mississippi, but it is a fungus disease that is becoming more prevalent. **Key symptom:** Powdery mildew is identified by white patches of fine, powdery growth on the upperside of leaflets. Patches are up to 1/2 of an inch in diameter and generally appear on the oldest foliage. Severely affected plants are weakened by the disease, resulting in reduced yields.

Target spot, another fungus disease (*Corynesporia cassiicola*), has been detected in greenhouse tomatoes at several locations across the state. Early symptoms of target spot first appear on foliage. Look for the **key symptom** to appear as small, water-soaked spots on the uppersurface of older leaves. The spots rapidly enlarge to form circular light- to dark-brown lesions with concentric rings. The concentric rings resemble the "target-spot" symptoms associated with early blight. Lesions are also formed on leaf petioles and stems.

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

Pythium root rot (*Pythium spp.*) is becoming an increasingly severe problem in Mississippi greenhouses. The species of this fungus that cause problems in the crop are easily introduced into the greenhouse environment via soil clinging to shoes, tools, and, frequently, contaminated

water supplies. A common source of *Pythium inoculum* is a nonsterile growth medium (e.g., river sand or other media piled on bare ground) where it becomes contaminated from underlying soil under wet conditions. *Pythium* root rot shows up most commonly when excessive amounts of water accumulate around roots. Pythium is a water mold type of fungus and is most aggressive when a "too heavy" growth medium is used and bags or other containers don't drain well. When this occurs, the fungus attacks juvenile roots and eventually the main root mass. **Key symptom:** Look for extensive areas of chocolate-brown to black roots on wilted, stunted plants with yellowish "unthrifty" appearing foliage.

Infected plants generally do not die and often produce new roots if moisture problems are corrected. Intact root systems from suspect plants should be submitted to a plant disease clinic for examination if symptoms are not clear-cut.

Fusarium crown and root rot (*Fusarium oxysporum f.sp.—radicis-lycopersici*) was first found in Mississippi greenhouse tomatoes in the late 1980's. This disease is almost impossible to control without the use of resistant varieties; thus, growers should become familiar with symptoms of the disease and realize the need for proper variety selection for use in those greenhouses where Fusarium crown and root rot has been detected.

The Fusarium crown and root rot (FCRR) fungus, after initially infecting secondary roots, moves into larger roots and eventually invades the plant's vascular system. Symptoms of FCRR include stunted growth and wilting on sunny days, especially if plants have heavy fruit loads. Infected plants may eventually die after repeated wilting. FCRR can be distinguished from Pythium root rot if the base of the stem is cut longitudinally. **Key symptom:** Look for dark- to reddish-brown discoloration of the vascular tissues. Discoloration is evident up 12 to 18 inches above the soil line, in contrast to Fusarium wilt, where discoloration may extend 3 to 4 feet high.

Bacterial Diseases

Plants affected by bacterial wilt (*Pseudomonas solanacearum*) rapidly wilt and die without exhibiting yellowing or leaf necrosis. When a wilted plant is cut near the soil line, the stem pith looks dark and water-soaked. However, these symptoms are not always readily detectable. **Key symptom:** Examine a cross-sectional piece of lower stem for a white to grayish exudate when the stem is pressed. In late stages, the stem may become hollow.

Test suspicious plants for bacterial wilt. The procedure is simple, and results can be evaluated in 2 to 5 minutes. Follow these steps:

- Cut a 2-inch-long section from the base of the stem.
- Fill a small, clean glass container with tap water.
- Suspend the stem (using a wire hanger, etc.) about 1/2 inch into the water.

Key symptom: Look for a thin, milky stream of bacterial cells to appear about 2 to 5 minutes after stem insertion into the water. The streaming is best observed when the container is observed at eye level with backlighting.

Pith necrosis (*Pseudomonas corrugata*) is sometimes referred to as bacterial hollow stem. Affected plants occasionally wilt and show a slight yellowing of lower foliage. **Key symptom:** On lower stems, look for brown, sunken, necrotic stem cankers. Longitudinal cuts through cankers reveal hollow stems, a characteristic symptom of the disease.

Virus Diseases

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

ToMV diagnosis may be difficult. Symptoms to ToMV vary with variety, age of plant at time of infection, and environmental conditions. Plants become stunted, leaves may exhibit mild to severe yellow-green mottling, crinkling, corrugation, stringing, or curling. Stems may develop necrotic streaks. Generally, fruit shows no symptoms, although severe strains may cause internal browning, necrotic pitting, or severe mottling.

Because of the wide array of possible symptoms, no key symptoms are given. Considering the contagious nature of ToMV and the ease by which the virus can be spread through pruning, fruit harvesting, and other routine activity, get disease confirmation when the disease is suspected. Submit specimens to a disease clinic for serological testing or microscopic examination of tissues for presence of virus-inclusion bodies. Remove diseased plants promptly.

Tomato spotted wilt virus (TSWV) currently is not a widespread problem in greenhouse tomatoes. Like ToMV, diagnosis of TSWV in greenhouse tomatoes can be difficult. Symptoms can be many and varied. TSWV symptoms can be confused with those caused by other viruses, fungal or bacterial pathogens, or nutritional disorders. Although TSWV is not widespread, one of the chief vectors of the virus, the Western flower thrips (several other thrips species are also known to transmit the virus), is becoming widespread across the Midsouth. This could mean that TSWV will become more of a problem in future production of greenhouse tomatoes.

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

Miscellaneous Diseases

Depending on your locale, other diseases could show up and present problems. For example, Sclerotinia stem

rot is an infrequent but potentially damaging disease in many areas. This is also true for Cercospora leaf spot, bacterial spot, speck, and canker. Ask your Extension agent for assistance in diagnosing diseases that do not fit the "key symptom" approach.

Disease Management

Diseases caused by fungi, bacteria, and viruses can quickly destroy a crop of greenhouse tomatoes when conditions are favorable for their development. However, if growers use a combination of recommended practices, diseases can be managed. Biological, cultural, sanitary, and chemical techniques are necessary, since no single practice effectively controls all diseases affecting the crop.

Biological (Resistant Varieties)

Biological management is the most economical and effective method of handling several important diseases. This refers primarily to use of varieties with disease resistance. Compared to the 1970's, when the commonly grown varieties lacked adequate levels of resistance, most modern greenhouse tomato varieties are resistant to one or more diseases that previously were limiting factors in production.

Variety			Disease resistance*	
Caruso	ToMV		C5	
Capello	ToMV		C5	
Dombello	ToMV		C5	
Perfecto	ToMV		C5	
Laura	ToMV	C2		
Dombito	ToMV	C2		
Jumbo		C2		
Match	ToMV		C5	FCRR
Switch	ToMV		C5	FCRR
Trust	ToMV		C5	FCRR
Blitz	ToMV		C5	FCRR

* ToMV = Tomato Mosaic Virus;
C2 = Leaf Mold Races A and B;
C5 = Leaf Mold Races A, B, C, D, and E;
FCRR = Fusarium Crown and Root Rot.

Cultural

Cultural management refers to practices associated with the production of the crop. This method is aimed at creating conditions unfavorable for disease development. Regulation of greenhouse relative humidity is critical, since moisture is the primary factor influencing plant infection by the fungi responsible for gray mold and leaf mold. Relative humidity must be above 90 percent for spore germination and infection to occur. Most bacterial diseases are also favored by high, relative humidity.

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

1. Keep the ventilators open an inch or so (or exhaust fans on at low capacity) when the heat comes on in the late afternoon. Cold air enters the house, while warm, moist air leaves. The cold, drier air entering is heated or further dried. Then, after 5 to 10 minutes, the ventilators are closed or fans turned off. A warm, dry air now exists in the greenhouse.

2. Moving air in the greenhouse helps reduce moisture on plant surfaces. The horizontal airflow system or the overhead polyethylene ventilation tube system will minimize temperature differentials and cold spots where condensation is likely to occur.

3. When extremely moist conditions exist in a greenhouse, it may be necessary to exchange the air one or more times during the night. Greenhouse supply companies sell controls that turn on the fans at predetermined times during the night.

Temperature control is also important. For example, greenhouse temperatures no lower than 70 degrees Fahrenheit limit development of gray mold. Fusarium crown and root rot and Pythium root rot are favored by cooler temperatures as well.

Pith necrosis appears to be most severe when plants are overfertilized with nitrogen; and it is likely that pythium root rot could be more of a problem if roots are injured by high soluble salts levels.

Pruning method may predispose stems to *B. cinerea* infection, since fewer stem lesions develop when petioles are cut or broken close to the stem than when removed 1 or 2 inches from the stem.

Sanitation

Sanitation is recognized by most growers as an integral part of effective disease management. Unfortunately, not all growers carry out a strict program in this area.

Before beginning a new crop:

- Rid the greenhouse of debris that could serve as future sources of fungus, bacterial, or viral inoculum.
- If diseases were a problem in the previous crop, think twice about reusing old growth containers. Do not reuse growth containers (e.g., rockwool slabs, poly bags) or growth medium from which diseased plants were removed. For a NFT or modified NFT system, use sodium hypochlorite (bleach), another suitable disinfectant, before new crop installation. Complete flush of the system following treatment is essential for removal of disinfectant that could be phytotoxic.
- Disinfect the greenhouse by spraying all surfaces with a 5- to 10-percent solution of sodium hypochlorite (household bleach). These percentage solutions can be obtained by adding 1 gallon of bleach to 19 gallons of water (5 percent) or 1 gallon of bleach to 9 gallons of water (10 percent). After about 15 minutes, rinse sprayed surfaces with plain water. This treatment is effective for most greenhouse disease microorganisms, but it must be used in combination with an overall program of good sanitation.

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

After crop installation:

• Have a "clean-up" room, e.g., to disinfect hands, clean shoes — in short, use any practice available to prevent introduction of disease organisms into the greenhouse.

• Restrict use of tobacco products if a ToMV-susceptible variety is being grown.

• Frequently disinfect tools and other equipment with sodium hypochlorite (bleach) at the rate of 1/2 gallon per 10 gallons of water. Dip for 5 to 10 seconds, drain, and use without rinsing.

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

• Consider using insect-barrier screens to cut down on movement (into the greenhouse) of thrips, aphids, and other potentially viruliferous insects.

• Observe plants constantly for any evidence of disease development. Promptly remove diseased plants; likewise, remove foliage that may be seriously diseased or is no longer contributing to plant growth. Diseased plants or diseased plant parts should be destroyed or carried far enough away from the greenhouse so as not to be a source of inoculum for reintroduction into the greenhouse.

Fungicides

The need for week-to-week fungicide application is minimized if the following procedures are followed: provide sanitary practices to limit fungus inoculum carryover from previous crops; control the greenhouse environment to prevent extended periods of high humidity, and other cultural practices described previously. If you want extra insurance, consider using Exotherm Termil. This is a recommended approach when climatic conditions have made it difficult to maintain relative humidity levels below 90 percent (e.g., during extended periods of overcast, cool weather) or when the crop has been injured in some way (e.g., by insecticide burn) and is, therefore, more susceptible to invasion by *Botrytis cinerea*.

The active ingredient in Exotherm Termil is chlorothalonil. This fungicide, used in the form of a smoke bomb, is effective for gray mold, leaf mold control, target spot, and it helps suppress powdery mildew. Exotherm acts as a protectant and has little or no effect after infection has occurred. Scout the crop daily to very closely observe plants for initial symptoms of disease; start an Exotherm Termil application program at the earliest indication of disease.

Note: Use one 3.5-ounce can of Exotherm Termil per 1,000 square feet of greenhouse area. Repeat weekly. Be sure all plant surfaces are dry. Close all doors, windows, and ventilators; post warning signs and take other precautions to prevent persons and animals from entering the area. **Do not** apply when greenhouse temperature is above 75 degrees Fahrenheit . **Follow other precautions outlined on the product label.**

Botran 75W and formulations of mancozeb (Dithane M-45, DF, and F-45) are also cleared for use in controlling diseases of greenhouse tomatoes. Additionally, copper-containing fungicides such as Kocide 2000 and Kocide 101 are approved for use for various bacterial diseases and leaf mold. **Refer to product labels for use directions.**

Pesticide Application Methods

There are several ways to apply pesticides to pests attacking greenhouse-grown tomatoes. The technique used is dictated by existing equipment, type and stage of development of the crop or pest, susceptibility of the crop to injury, and economics.

Residues are left on plants when sprays, mists, or dusts are used, and residues continue to control pests after application. Fine droplets are propelled into the air by smokes, fogs, and aerosols to kill existing insects, whether they are on the crop, beneath benches, or elsewhere. However, effective residues are not left by these latter methods of application, resulting in possible repeated applications or the use of these systems used in conjunction with sprays, mists, or dusts.

Spray Application

Spraying is the most common method of pesticide application in the greenhouse. Generally, most pesticides are formulated for mixing with water. Emulsifying concentrates (EC) are formulated in an oily preparation with an emulsifying agent that renders the oil miscible in water.

Pesticides as wettable powders (WP) are solid particles, usually clays, that dispense in water. Operate an agitator in the spray tank to prevent particles from settling out. WP formulations are less phytotoxic to plants than are EC formulations of the same pesticide. Mix WP formulations first in a bucket and then pour it into the spray tank. This avoids solid deposits that may plug nozzles.

A spraying system movable on overhead tracks is a good system for overhead applications and between rows where rows are separated enough to permit the use of drop nozzles. Otherwise, spray penetration into the plant canopy is best achieved from a distance of 16 to 18 inches. It offers the ultimate in worker safety and can be automated. These systems normally use a Spraying Systems Co. TX4 to TX6 nozzle tip or equivalent. The fine spray droplets produced by the smaller, hollow cone tips are more prone to drift and can be moved better into the plant canopy with fan-generated air currents than can larger drops in still air.

Calibrate on an enclosed volume or sprayed area basis. One gallon per 1,000 square feet equates to 43.56 gallons per acre. This rate thoroughly wets and approaches runoff on many smooth and waxy leaf surfaces if plants are 18 to 24 inches tall and cover about 50 percent of the surface area. Compute and measure accurately the amount of pesticide to be applied to the greenhouse. Apply all the solution to the planted area as well as the sprayer rinse water after the application is complete.

Surfactants may be needed if plants have a waxy cuticle covering them. These include spreaders, wetters, or

spreader-stickers that lower the surface tension, which increases the ability of the spray to spread out over the plant surface.

There are a number of surfactants on the market. Use label-recommended rates, because too much surfactant can cause plant distortion. Mild liquid household detergent can also be used at the rate of 1 pint per 100 gallons or 1/2 teaspoon per gallon. Wettable powders generally need a surfactant added, since EC formulations usually contain an emulsifying agent that is itself a surfactant.

Some sprays are corrosive to the spray equipment. If left in the hose or sprayer, they can be dangerous to workers. Solid deposits, with time, can occur in the nozzles, lines, or tank. If left standing for some time, some pesticides break down to a form injurious to plants. For these reasons, it is important to empty and rinse out the sprayer after use, then pump clean water through the entire system.

Dust Application

Some pesticide dusts may be used in greenhouses. The carriers for dust formulations are talc, clay, diatomaceous earth, or similar filler. Hand-cranked units to large motorized dusters may be used for small greenhouses. However, dusts are not commonly used for pest control because of the visible residue left on the plants.

Ultralow-Volume (ULV) Application

ULV applicators apply pesticides at 10 to 20 times the concentration encountered in hydraulic sprayers. The advantages of using ULV pesticide application include (1) the use of less pesticide, (2) reduction in time required for application, and (3) the possibility of highly uniform coverage. However, there is a disadvantage of possibly applying too little or too much pesticide to local areas.

Aerosol Application

Some insecticides (no fungicides) may be purchased in cylinders under pressure. When released into the lower pressure of the atmosphere, these insecticides expand into a gas and move at a high velocity, carrying small droplets (15 to 20 microns) with them. These small droplets drift on the air currents, quickly dispersing throughout the entire greenhouse atmosphere and onto the upper and lower surfaces of plants. This type of pesticide application is used for immediate kill of existing insects, leaving little residue on plants.

Be sure to determine the volume of the greenhouse by multiplying the width times the length times the height (W x L x H). The quantity of insecticide applied is related to the volume of the greenhouse.

Aerosol bombs should be used preferably when the temperature is 70 degrees - 80 degrees Fahrenheit. Improper distribution of insecticide occurs when temperature is below 60 degrees Fahrenheit, and injury can occur to plants if temperature is above 85 degrees Fahrenheit. Apply aerosols on a calm day and keep the greenhouse closed for at least 2 hours for maximum control. Ventilate house well before reentry. Plants should be well watered and the foliage dry at the time of application to help avoid injury.

Fog Application

A few insecticides and fungicides are available in oil-based-carrier preparations for use in fogging equipment. This method of application is similar to that of aerosols. Follow the same precautions. The pesticide is heated by a device to form small droplets (10 to 60 microns) that are propelled into the greenhouse atmosphere in the form of a white fog, which is easily seen (to know all areas are treated equally). Do not direct fog toward the plants, because heavy deposits and hot exhaust can injure plants. Flowers of plants, more so than foliage, tend to be more susceptible to fogging injury. Aim the fog into the aisles.

Smoke Application

No special equipment is needed when applying smokes. Small containers of a combustible formulation containing a pesticide are placed along the center aisle of the greenhouse and ignited. The pesticide is carried in the smoke throughout the greenhouse.

Smokes are generally less phytotoxic to plant foliage and flowers than are aerosols and fogs. The dosage rate is important; therefore, the volume of the greenhouse must be correctly calculated and divided by the volume you can treat to determine how many cans to use. Further precautions are the same as for aerosols and fogs.

Worker Protection For Greenhouse Employees

- Read and follow label directions.
- Use personal protective equipment (PPE) as specified on the label.
- Exercise extreme care in enclosed areas. Use respirator or self-contained breathing apparatus.
- Ventilate properly before reentry.
- Post reentry periods as per Worker Protection Standard.
- Use proper care and maintenance of personal protective equipment. Inspect gloves for leaks — wash off after use and before removal.
- Know poisoning symptoms for material being used.
- Work in pairs or have someone periodically check on you and other workers.

By **Dr. Frank Killebrew,** Extension Plant Pathologist, Deceased, **Dr. Pat Harris,** Extension Area Entomology Specialist, Retired, and **Herbert Willcutt,** Extension Professor, Agricultural and Biological Engineering.

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