Common Diseases of TOMATOES

In Mississippi, tomatoes are produced commercially both in the field and in enclosed structures (high tunnels and greenhouses). They are also a very popular garden plant among homeowners. Tomato production, whether for commercial or personal use, is not always an easy task. A variety of ***disorders***, insects, ***diseases***, and pests may cause problems during any given growing season and may damage a crop, leading to reduced or poor-quality yields.

A number of disease-causing organisms (***pathogens***) can ***infect*** tomatoes and cause disease. Many of the most common diseases that affect tomatoes in Mississippi are caused by various fungi, bacteria, and viruses. A few fungus-like organisms (***oomycetes***) commonly called water molds also cause troublesome diseases in Mississippi.

Diagnosis is the first step in disease management. Identifying the cause of a problem is necessary before appropriate management methods can be taken. This publication provides information on many of the most common diseases of tomatoes that occur in Mississippi, as well as descriptions of the ***signs*** (the visible presence of a pathogen) and ***symptoms*** (a plant's reaction to infection with a pathogen) associated with those diseases. Several plant pathology-related terms are used in these descriptions. These terms are formatted in ***bold italics*** at their first mention within the text and are defined in the Glossary of Plant Pathology Terms at the end of this publication. General disease management methods that can be used to prevent or reduce disease are also described following the descriptions of the common diseases.

Notes: Many diseases of tomatoes occur both in the field and in enclosed structures; however, because of the unique nature and environmental conditions present in enclosed structures, some diseases are more common in these structures, whereas others are more common in the field. Additionally, some disease management methods for tomatoes grown in greenhouses are unique to those structures since the environment in these structures can be manipulated.

While the information in this publication may be relevant to tomato production and disease management in any location, this publication does not focus on methods that pertain to managing diseases of tomatoes in the greenhouse. To learn about common diseases of tomatoes that more commonly occur in greenhouses and how to manage them, see MSU Extension Publication 1861 *Greenhouse Tomatoes: Pest Management in Mississippi*.

Additionally, while some disorders are often mistaken to be diseases or are sometimes referred to as abiotic (nonliving) diseases, disorders are also not described in this publication. Common disorders in tomatoes are, however, described in MSU Extension Publication 2975 *Tomato Troubles: Common Problems of Tomatoes.*

DISEASES OF TOMATOES

Anthracnose (fungi: *Colletotrichum* spp.) is primarily a problem on fruit that is ripe (or overripe), although leaves, stems, and roots may become infected. Fruit that is not yet ripe may also become infected; however, symptoms will only appear when the fruit begins to ripen. Moist conditions promote disease development. The pathogens can survive from crop to crop on plant debris and in the soil and have a broad host range. Splashing water from rain or overhead irrigation can spread the pathogens.

Signs/symptoms: Small, slightly depressed, circular ***lesions*** (localized areas of diseased tissue) develop on ripe fruit. These lesions may enlarge, become more sunken, and merge together. Eventually, small, black spots (microsclerotia) develop in the tan centers of lesions. When moist conditions are present, salmon-colored spores, visible in masses, may be produced on the surfaces of lesions.

Management: crop rotation, cultural practices, sanitation, fungicides

Bacterial canker (bacterium: *Clavibacter michiganensis* subsp. *michiganensis*) can be a significant disease in tomatoes grown in the greenhouse. The pathogen is seedborne and can survive in infected plant debris and weed hosts and on surfaces and production supplies (stakes, trays). The pathogen can also be spread from plant to plant on workers' hands and by splashing water and pruning.

Symptoms: A variety of symptoms may be produced in tomatoes infected with the bacterial canker pathogen. Wilting is the most noticeable symptom. Wilting typically begins in the lower portion of the plant and then moves up; however, wilting can begin at the point of pathogen entry when plants are wounded. Stems may develop dark streaks that may split to expose a brown ***canker*** (defined, dry, necrotic lesion). Light yellow to brown streaks that eventually turn reddish-brown develop in vascular tissues and are more clearly visible at plant nodes. Adventitious roots may also develop on stems. Leaflet margins may turn brown and be bordered by yellow margins (**Figure 1**). Bird's eye spots (tan to brown spots surrounded by creamy-white halos) may develop on fruits (**Figure 1**).

Management: clean planting material, seed treatment, sanitation, weed control, crop rotation

Figure 1. Marginal burning on tomato leaflets and bird's eye spots on tomato fruits with bacterial canker. Photo by M. A. Hansen, Virginia Tech, Bugwood.org.

Bacterial speck (bacterium: *Pseudomonas syringae* pv. *tomato*) can be a serious disease of tomatoes and can be difficult to control when disease pressure is high and favorable environmental conditions are present. High humidity and cool temperatures favor disease development. The pathogen is seedborne and can also be spread by splashing water, contaminated tools and equipment, and workers. The pathogen can also survive from season to season in crop debris if conditions are favorable. Pathogen resistance to copper has been reported; however, it is unknown if resistant pathogen populations are present in Mississippi.

Figure 2. Brown lesions on a tomato leaflet and petiole with bacterial speck. Photo by G. Holmes, Cal Poly – San Luis Obispo, Bugwood.org.

Symptoms: Round, dark brown to black lesions develop on leaflets; over time, a yellow halo may develop around lesions (**Figure 2**). Large areas of leaflets may die when lesions coalesce (grow together). Lesions may also form on stems, petioles, peduncles, pedicels, and sepals; these lesions are often elongated. Dark lesions also develop on fruit. These fruit lesions may be surrounded by a dark green halo. *Note*: Symptoms of bacterial speck are very similar to and can be easily confused with those of bacterial spot.

Management: pathogen-free seed, seed treatment, cultural practices, sanitation, crop rotation, fungicides

Figure 3. Lesions on tomato leaves with bacterial spot. Photo by E. Sikora, Auburn University, Bugwood.org.

Bacterial spot (bacteria: *Xanthomonas* spp.), like bacterial speck, can be a serious disease of tomatoes and can be difficult to control when disease pressure is high and favorable environmental conditions are present. Abundant precipitation and warm temperatures favor disease development. The pathogen can be spread on seeds, by wind-driven rain, and when handling plants. All aboveground plant parts may be affected. Pathogen resistance to copper has been reported; however, it is unknown if resistant pathogen populations are present in Mississippi.

Symptoms: Round, brown lesions develop on affected tissues (**Figure 3**). As lesions coalesce, dark streaks may form on affected tissues. Leaves with many lesions may develop a yellow appearance. Leaves on which lesions coalesce may become ***blighted*** (rapid, extensive damage or destruction). Dead foliage may remain on the plant. Lesions on leaflets may also develop a shot-hole appearance in which the center of the lesion falls out of the leaflet. On fruit, lesions appear as raised blisters that become brown and scabby **(Figure 4**). *Note*: Symptoms of bacterial spot are very similar to and can be easily confused with those of bacterial speck.

Management: pathogen-free seed, seed treatment, cultural practices, sanitation, crop rotation, fungicides

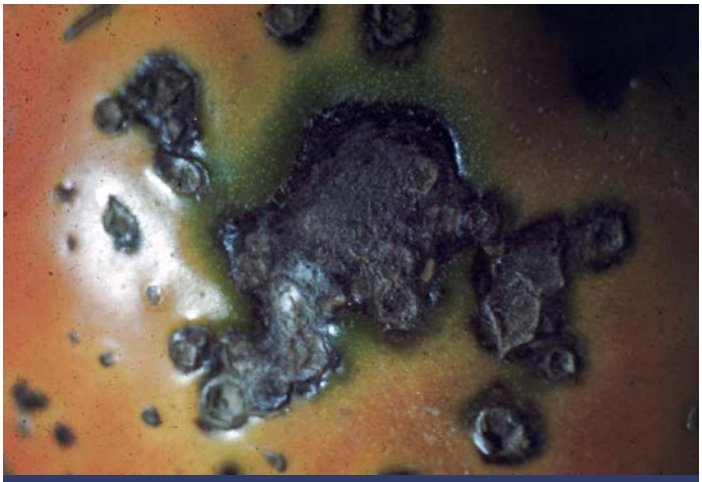

Figure 4. Lesions on a tomato fruit with bacterial spot. Photo by R. W. Samson, Purdue University, Bugwood.org.

Bacterial wilt (bacterium: *Ralstonia solanacearum*) can be a devastating disease of both field and greenhouse tomatoes. High soil temperatures and high moisture levels favor disease development. The pathogen, which infects many crops in addition to tomatoes, can survive in the soil for long periods of time even in the absence of a susceptible crop. Bacterial wilt is difficult to manage once the pathogen is established in a field. The pathogen can also be spread by contaminated water, tools, and equipment, as well as by workers.

Note: The bacterium *R. solanacearum* is divided into five races (subgroups), not all of which are present in the United States. The race that commonly infects tomato is

Figure 5. Brown stem lesion on a tomato with bacterial wilt. Photo by D. Ferrin, LSU AgCenter, Bugwood.org.

Figure 6. Vascular discoloration in a tomato with bacterial wilt. Photo by D. Ferrin, LSU AgCenter, Bugwood.org.

Figure 7. Bacterial streaming from a stem of a tomato plant with bacterial wilt. Photo by J. Brock, University of Georgia, Bugwood.org.

Race 1 and is endemic throughout the southeastern United States. However, all races of the pathogen are considered to be select agents by the United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS). As such, the diagnosing laboratory must handle samples testing positive for this bacterium according to USDA protocol, and positive diagnoses must be reported to USDA APHIS.

Signs/symptoms: Plants with bacterial wilt rapidly wilt and die without showing symptoms of ***chlorosis*** (yellowing of plant tissue) or leaf ***necrosis*** (death of plant tissue). Wilting is usually permanent. A brown lesion may be visible on the outside of the stem near the base of the plant (**Figure 5**). When cut near the base of the stem at the soil/media line, the inside of the stem may be dark and water-soaked (**Figure 6**). In plants with advanced infections, the stem may be hollow. Cut stems will often exhibit profuse bacterial streaming (**Figure 7**).

A quick "field test" can be performed 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 vertically (using a wire hanger, paper clip, or nail) in a clear container of water so that the base of the stem is a good distance from the bottom of the container; place this setup where it will remain undisturbed.

3. Observe the setup after a few minutes for a thin, milky stream flowing from the stem to the bottom of the container (**Figure 7**).

Management: clean planting material, resistance (rootstocks), cultural practices, sanitation, crop rotation

Buckeye rot (oomycetes: *Phytophthora nicotianae* var. *parasitica*, *P. capsici*, and *P. drechsleri*.) is a common disease of tomatoes in the southeastern United States. High humidity and warm temperatures favor disease development. Disease is most severe in soils with plenty of moisture. The pathogen can be spread by contaminated or splashing water.

Signs/symptoms: A brown, oily-looking lesion develops on infected fruit (**Figure 8**). Over time, lesions enlarge and may cover large portions of the fruit. Concentric rings are typically visible within the lesion. When moist conditions are present, a white, cottony fungal growth may develop on the surface of the lesion. Fruit that become infected are often in direct contact with the soil or are low to the ground. These low-hanging fruit may become infected as a result of ***infested*** (contaminated with a pathogen) soil being splashed onto them. Foliage is not infected.

Management: site selection, staking, mulching, cultural practices, crop rotation, fungicides

Figure 8. Symptoms of buckeye rot on tomato fruit. Photo by D. Ferrin, LSU AgCenter, Bugwood.org.

Early blight (fungi: *Alternaria solani* and *A. tomatophila*) is a common disease of tomatoes grown in the field. Leaves, stems, and fruits may be affected. Disease typically starts at the bottom of the plant and moves up. High humidity and mild temperatures favor the pathogen. The pathogen is seedborne and can survive on infected plant debris.

Symptoms: Circular or elongated, brown lesions with concentric rings develop on infected plant tissues (**Figures 9 and 10**) and enlarge over time. The leaf tissue surrounding lesions often becomes chlorotic (**Figure 9**). Symptoms can occur on leaves, stems, and fruits.

Management: crop rotation, sanitation, staking, mulching, fungicides

Figure 9. Early blight lesions on a tomato leaflet. Concentric rings are visible in the lesions. The leaf tissue surrounding the lesions on the stem is chlorotic. Photo by R. A. Melanson, MSU Extension, Bugwood.org.

Figure 10. Early blight lesions on a tomato stem. Concentric rings are visible in the lesions. Photo by R. A. Melanson, MSU Extension, Bugwood.org.

Fusarium wilt (fungus: *Fusarium oxysporum* f. sp. *lycopersici*) is considered to be a warm-weather disease. The pathogen, which is divided into three ***races***—all capable of causing disease, is soilborne and can survive in the soil for many years. It is commonly transmitted on infected transplants and through contaminated soil or equipment. Infection is favored by root wounds, which may be caused by root-knot ***nematode***s. Cultivars resistant to one or more races of the fungus are commonly used to manage disease. *Note:* Other species of *Fusarium* also infect and cause diseases, such as Fusarium crown and root rot, in tomatoes.

Symptoms: The most common symptoms of Fusarium wilt include wilting and chlorosis of leaves. Plants just beginning to show symptoms may wilt during the hottest part of the day and then recover overnight. Chlorosis of leaves typically occurs on only one side of the plant initially but may develop over the entire plant as the disease progresses. The vascular tissue near the base of infected plants may also exhibit a dark red to brown coloration.

Management: resistance, crop rotation, cultural practices, sanitation

Gray leaf spot (fungi: *Stemphylium* spp.) can be a devastating disease of tomatoes in locations where susceptible varieties are grown. The pathogen can survive on plant debris and susceptible hosts and can be spread by wind.

Symptoms: Small, round to oblong, randomly scattered lesions develop on the upper and lower surfaces of leaflets. Large areas of leaflets may become necrotic when lesions coalesce. Cracks may develop in the center of the lesions, and entire leaves may begin to yellow. Affected leaves may quickly die and turn brown before falling to the ground.

Management: disease-free plants, resistance, fungicides

Gray mold (fungus: *Botrytis cinerea*), sometimes referred to as Botrytis gray mold, is a common disease of tomatoes grown in enclosed structures and can spread rapidly. The pathogen favors high humidity and cool temperatures and requires free moisture for spore germination. Wind/air movement can spread spores. All aboveground plant parts may be affected, but the pathogen does not actively infect healthy tissue. New infections commonly occur at pruning wounds, and dead tissue often serves as a source of entry for the pathogen. The pathogen can also survive from season to season in the form of ***sclerotia*** (compact masses of fungal ***hyphae***).

Figure 11. *Botrytis* lesion on a tomato leaflet. Gray fungal growth is visible in the area of the lesion on the edge of the leaflet. Photo by R. A. Melanson, MSU Extension, Bugwood.org.

Figure 12. *Botrytis* lesion on a tomato stem near a pruning wound. Gray fungal growth is present near the center of the stem lesion. Photo by A. Henn, MSU Extension.

Signs/symptoms: Tan or gray lesions typically form at the tips of leaflets and become covered with brown or gray fungal growth (**Figure 11**). Dead flowers and dying calyx tissue may also become infected. Stem cankers may also develop, often as a result of pathogen invasion at a pruning

wound (**Figure 12**). These typically large, brown cankers may girdle the stem, causing wilting and plant death above the canker. Another symptom associated with gray mold is the production of "ghost spots," small, whitish rings or halos that develop on the fruit (**Figure 13**). These "ghost spots" are spots where *Botrytis* spores germinated but failed to infect the fruit. Fruit that does become infected becomes water-soaked and soft.

Management: reduce leaf wetness, proper pruning, sanitation, fungicides

Figure 13. Ghost spots on a ripening tomato fruit. Photo by A. Henn, MSU Extension.

Late blight (oomycete: *Phytophthora infestans*) development is favored by moist weather, cool nighttime temperatures, and warm daytime temperatures. Temperatures greater than 86ºF are not favorable for disease development. The pathogen is seedborne and can survive on susceptible hosts and weeds. *P. infestans* also infects and causes late blight in potatoes.

Signs/symptoms: Symptoms can develop on all aboveground plant parts. Lesions on leaves begin as small, water-soaked spots. These lesions become pale-green to brown and can quickly expand to cover large areas of a leaf (**Figure 14**). When moist weather is present, gray to white pathogen growth may develop on the lower surface of leaf lesions. Infected foliage turns brown, withers, and dies. Brown, greasy lesions develop on infected fruits. These lesions can expand to cover the entire fruit.

Management: disease-free planting material, sanitation, fungicides

Figure 14. Late blight lesion on a tomato leaflet. Photo by G. Holmes, Cal Poly – San Luis Obispo, Bugwood.org.

Leaf mold (fungus: *Passalora fulva*, formerly *Cladosporium fulvum* and *Fulvia fulva*) is a common disease of tomatoes grown in enclosed structures, but it occasionally occurs in field-grown tomatoes. High humidity and moderate temperatures favor disease development. The pathogen can survive on crop residue. Spores can be spread by rain and wind and on tools, clothes, and insects.

Figure 15. Yellow leaf mold lesions on the upper surface of tomato leaflets. Photo by R. A. Melanson, MSU Extension, Bugwood.org.

Figure 16. Olive-green fungal growth on the lower surface of a tomato leaflet with leaf mold. Photo by R. A. Melanson, MSU Extension, Bugwood.org.

Signs/symptoms: Pale green or yellow lesions with irregular margins develop on the upper surfaces of leaflets (**Figure 15**). Olive-green, velvet-like fungal growths develop on the undersides of the leaflets directly beneath yellow lesions (**Figure 16**). Infected leaves typically collapse and wither. Leaf mold is a foliar disease; symptoms are only expressed on leaflets.

Management: pathogen-free seed, seed treatment, resistant varieties, sanitation, fungicides

Powdery mildew (fungi: *Leveillula taurica* and *Oidium neolycopersici*), unlike most tomato diseases that tend to increase in severity in the presence of plentiful moisture, can develop during periods of dry weather. Disease development favors high humidity. The pathogens can be easily spread by wind.

Signs/symptoms: Powdery white patches of fungal ***mycelium*** develop on the upper surfaces of leaves infected with *O. neolycopersici* (**Figure 17**). These leaves may become chlorotic and eventually necrotic. Light green or bright yellow, irregularly shaped lesions typically appear on the upper surfaces of tomato leaflets infected with *L. taurica*.

Management: resistance, fungicides

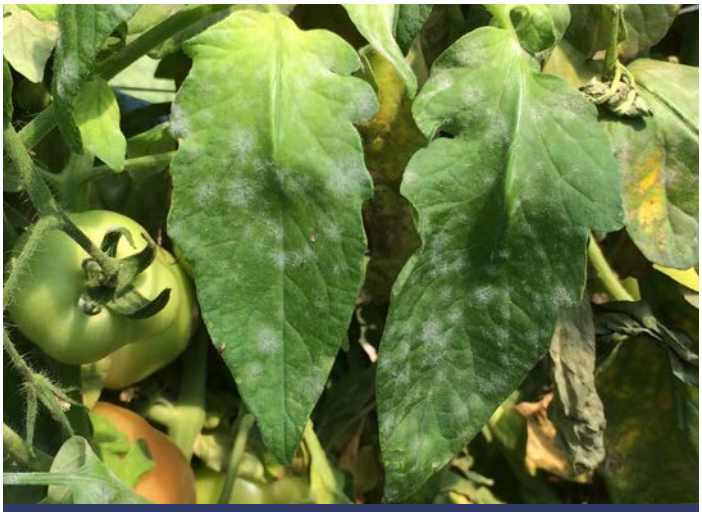

Figure 17. White fungal growth on the upper surface of tomato leaflets with powdery mildew. Photo by R. A. Melanson, MSU Extension, Bugwood.org.

Pythium damping-off and stem rot (oomycetes: *Pythium* spp.) can result in plant loss and poor stand establishment of seedlings in both the field and greenhouse. Damping-off can occur both pre- and post-emergence. *Pythium* species can survive in the soil for long periods of time in the absence of the host and can persist indefinitely in the soil on organic matter. However, pathogen growth is favored by certain factors, including the presence of moisture.

Note: Other pathogens can also cause damping-off. It is important to determine which pathogen is causing the damping-off so that appropriate fungicides can be selected for treatment.

Signs/symptoms: In pre-emergence damping-off, a dark brown to black lesion often develops on germinating seedlings. In post-emergence damping-off, a dark-colored, water-soaked lesion often develops on roots and extends onto the stem above the soil line. Infected seedlings typically wilt and may fall over at the point of the stem lesion before dying. Plants with root infections that are not severe may simply be stunted.

Management: seed treatment, cultural practices, sanitation, fungicides

Septoria leaf spot (fungus: *Septoria lycopersici*) can destroy tomato foliage and reduce yield. Though fruit infection is uncommon, the destruction of foliage can lead to fruit failure or make fruit prone to sunscald. Disease development is favored by long periods of moderate temperatures, dew, and high humidity. The pathogen

Figure 18. Septoria leaf spot lesions on a tomato leaflet. Photo by B. Watt, University of Maine, Bugwood.org.

can overwinter on plant debris of susceptible hosts and can survive on production equipment. Tomato seeds can be infected. The pathogen can be spread by rain and by workers, insects, and equipment when plants are wet.

Signs/symptoms: Symptoms can develop on the calyx, leaves, and stems. Round lesions with dark margins and tan to gray centers develop on leaves (**Figure 18**). Black fruiting bodies (pycnidia) develop in the center of lesions approximately 2 weeks after infection (**Figure 18**). A thin, yellow halo often develops around lesions on leaflets (**Figure 18**).

Management: crop rotation, weed management, cultural practices, sanitation, fungicides

Southern blight (fungus: *Sclerotium rolfsii*), sometimes called southern stem rot, can be a significant problem in tomato production. High temperatures and moist conditions favor disease development. The pathogen can survive as sclerotia for years in soil or plant debris and can be easily spread through the movement of infested soil and infected plant material. Southern blight can be

Figure 19. White fungal growth and round, tan and brown sclerotia of the southern blight pathogen. Photo by R. A. Melanson, MSU Extension, Bugwood.org.

easily diagnosed in the field if the characteristic signs of this pathogen are present.

Signs/symptoms: The most noticeable symptom of southern blight is a sudden and permanent wilt caused by the rotting of the stem. A brown to black stem lesion that girdles the stem is often visible near the soil line of infected plants. When moist conditions exist, white fungal mycelia develop on the stem lesion, followed by the development of round, tan to brown sclerotia (**Figure 19**). Fruit in contact with infested soil may also be infected. Infected fruits initially appear sunken and yellow at the infection site and become water-soaked and soft before collapsing. White mycelium and sclerotia typically develop on infected fruits.

Management: crop rotation, deep tilling, fungicides

Target spot (fungus: *Corynespora cassiicola*) can be a severe problem in both the field and greenhouse. Long periods of high moisture and moderate temperatures (68–82°F) favor disease development. Pathogen sporulation is greater on the lower leaf surface than on the upper leaf surface.

Signs/symptoms: Symptoms may develop on leaves, petioles, stems, and fruit. Symptoms on leaflets begin as small, water-soaked lesions that expand and become light brown and circular (**Figure 20**). These lesions often develop a target-like appearance. Yellow halos develop around

Figure 20. Target spot lesions on tomato leaflets. Leaflet lesions have a target-like appearance and are typically surrounded by chlorotic tissue. Photo by T. C. Barickman, MSU Extension/MAFES.

individual lesions (**Figure 20**). Lesions may coalesce and result in the collapse of leaflet tissue. Similar lesions develop on petioles and stems, but these are more elongate than those on leaves. These lesions may girdle petioles and stems and result in leaflet or leaf collapse. On young fruit, lesions begin as brown, sunken spots the size of a pinpoint, but they can develop into craters. On ripe fruit, large, circular lesions with brown centers can develop. A crack often develops in the centers of the lesions on ripe fruit.

Management: fungicides

Timber rot (fungus: *Sclerotinia sclerotiorum*), also called white mold or Sclerotinia stem rot, can cause problems in tomatoes as well as many other vegetables. Disease development is favored by cool, moist weather. Free moisture and high humidity are also important for disease development. Dead or senescent tissue, often fallen flowers, serves as a necessary energy source for the fungus before it can infect healthy tissues.

Signs/symptoms: Disease typically begins as water-soaked areas near leaf axils or in stem joints. Stems become soft once infected and eventually become light gray or tan and have a bleached appearance (**Figure 21**). When environmental conditions are favorable, white

Figure 21. White mycelial growth and black sclerotia present inside a timber rot stem lesion on a tomato plant. Photo by B. Watt, University of Maine, Bugwood.org.

mycelium often develops on or in infected stems. Black sclerotia that look like rat droppings are often present on the fungal mycelium or inside infected stems (**Figure 21**). These sclerotia are typically black on the outside and white on the inside. Fruit may also be infected. Infected fruits typically turn gray and develop a watery rot. The characteristic white fungal mycelium and black sclerotia may also develop on infected fruits.

Management: cultural practices, deep-plowing, fungicides

Tobacco and tomato mosaic (viruses: *tobacco mosaic virus*, TMV, and *tomato mosaic virus*, ToMV) are caused by two different but similar viruses. ToMV will be discussed in detail here; TMV is discussed in detail in MSU Extension Information Sheet 1665 *The Plant Doctor – Tobacco Mosaic Virus*. ToMV is sap-transmissible and can easily be transmitted from plant to plant on workers' hands and clothes and on tools. Seed may be contaminated. The virus is very persistent and can also survive in plant debris for various lengths of time depending upon various conditions.

Symptoms: Symptoms in tomatoes vary in intensity depending on the strain of ToMV, cultivar, timing of infection, and environmental conditions. However, leaves of plants infected with ToMV are often ***mottled***

(characterized by irregular patterns of light and dark areas of tissue). Plants may be stunted and produce smaller leaves that are curled or deformed. Fruit of infected plants may ripen unevenly, be reduced in size, develop yellow rings, or have internal browning. The number of fruit produced on infected plants may also be reduced.

Management: resistance, seed treatment, sanitation, avoid tobacco use

Tomato spotted wilt (virus: *tomato spotted wilt virus*, TSWV) can cause significant losses in tomatoes. The virus has a wide host range, including many weed species. Adults of seven species of thrips transmit TSWV. Thrips larvae acquire the virus after a minimum of 30 minutes or fewer of feeding on infected plants. The thrips retain the virus through adulthood. Transmission does not occur until approximately 3 to 7 days after acquisition, after which transmission can occur after feeding on noninfected tissues for 5 minutes or fewer. Adult thrips remain infective their entire lives. Resistant varieties may still develop symptoms.

Figure 22. Bronze coloration of leaflets in a tomato with tomato spotted wilt. Photo by A. Henn, MSU Extension.

Figure 23. Symptoms of tomato spotted wilt on tomato fruits. Photo by W. Brown Jr., Bugwood.org.

Symptoms: Typically, leaves of plants infected with TSWV develop numerous small, dark spots as well as a bronze coloration (**Figure 22**). Streaks may develop in stems of infected terminals. Plants may be stunted and leaves may droop to resemble a wilt. Plants that become infected before fruit set may not produce fruit. Plants that become infected after fruit set will have green fruits with slightly raised areas with concentric rings and ripe fruits with chlorotic ringspots with red and white or yellow concentric rings (**Figure 23**).

Management: resistance, vector management

Tomato yellow leaf curl (virus: *tomato yellow leaf curl virus*, TYLCV) is one of the most devastating virus diseases of tomatoes, and total yield loss has been reported when vector populations were high. TYLCV is transmitted by adult whiteflies. Whiteflies can acquire the virus from feeding on an infected plant in approximately 15 minutes and can transmit the virus after approximately 6 hours. Virus transmission to noninfected plants can occur in approximately 15 minutes of feeding, and whiteflies can retain the virus for several weeks. Tomatoes infected at an early age incur greater yield losses than those infected at an older age. TYLCV is capable of infecting numerous hosts. These hosts can serve as reservoirs of the virus. Resistant varieties of tomatoes can also be infected. These varieties can produce acceptable yields despite infection; however, resistance can be overcome when inoculation pressure is high and infection occurs early.

Symptoms: Infection with TYLCV causes severe stunting, flower abscission, and significant reductions in yield. Leaves are reduced in size and may exhibit upward curling (cupping), mottling, or chlorosis of leaf margins (**Figure 24**). Fruit production is often reduced due to the abscission of flowers.

Management: resistance, vector management, sanitation, cultural practices

Figure 24. Symptoms of tomato yellow leaf curl in a tomato. Photo by D. Ferrin, LSU AgCenter, Bugwood.org.

Figure 25. Verticillium wilt lesions on a tomato leaflet. Photo by G. Holmes, Cal Poly – San Luis Obispo, Bugwood.org.

Verticillium wilt (fungi: *Verticillium albo-atrum* and *V. dahliae*) is typically a cool-weather disease. The fungi that cause Verticillium wilt are soilborne and can survive in infected plant debris or in the soil in the absence of a host for several years. In the plant, the pathogen spends much of the disease cycle in the water-conducting tissue (xylem). Disease severity may be increased when certain nematode species are present.

Symptoms: Visible symptoms often develop only in the later stages of infection. Diseased plants typically exhibit mild to moderate wilting during the hottest part of the day but recover at night. Leaflets develop marginal and interveinal chlorosis. V-shaped lesions, characteristic of this disease, often develop on leaflets (**Figure 25**). Vascular discoloration is visible in stems.

Management: resistance, crop rotation, sanitation, fumigation

DISEASE MANAGEMENT

Biological Management

Plant cultivars that have disease resistance/tolerance. The use of disease resistance, through the use of disease resistant/tolerant varieties, is the best way to manage plant diseases. A number of tomato varieties recommended for planting in Mississippi have disease resistance/tolerance to one or more diseases.

The disease resistance package, the combination of all disease resistance present in a particular variety, is often listed on seed packages, in seed company catalogs, or on seed company websites. Disease resistance codes are often used to indicate to which diseases a particular variety has resistance. For example, "L" may stand for gray leaf spot resistance, while "TSWV" typically stands for tomato spotted wilt virus resistance. Consult the seed company's key of disease resistance codes for code definitions.

Heirloom varieties, which are favored by some growers, generally do not have resistance to disease.

Use biological products. A number of biological products that use various microorganisms or biological agents, such as bacteria or various products produced by microorganisms, are available for use against various tomato diseases. These products tend to work best when they are used before the appearance of disease. Many of these products are approved for use in organic production.

A partial list of biological products approved for use in organic production by the Organic Materials Review Institute (OMRI) is provided in MSU Extension Publication 2036 *Organic Vegetable IPM Guide*. Additional products may be found in the latest edition of the *Southeastern U.S. Vegetable Crop Handbook* (available online at ***https://www.greenbook.net/ResourceCenter/ProduceProductionGuides***). A complete list of products approved for use in organic production by the OMRI can be accessed at ***www.omri.org***.

Cultural Management

Choose a good planting site. Some diseases, such as damping-off and root rots, occur more frequently in soils that do not drain well. To reduce the occurrence of these diseases, tomatoes should be planted on a site that has proper drainage and does not hold water. If drainage is a problem, raised beds can be used to help promote drainage.

Use practices that promote airflow and reduce leaf wetness. Cultural practices that promote airflow and reduce leaf wetness can help to reduce disease development; however, these practices may not be sufficient in managing diseases if favorable environmental conditions and high ***inoculum*** pressure are present. Leaf wetness may be reduced by increasing plant spacing, pruning plants, and avoiding the use of overhead irrigation. Controlling weeds may also help promote airflow since heavy weed growth can reduce air circulation and promote humid conditions around plants.

In greenhouses, horizontal fans may be used to increase airflow and reduce leaf wetness. Certain ventilation practices at appropriate times can also help to reduce the formation of condensation on plant surfaces in the greenhouse.

Rotate crops. Several pathogens that cause disease in tomatoes can persist from season to season in the soil. When a susceptible crop is planted year after year, pathogen inoculum can build up in the soil. Some pathogens have narrow host ranges and can only infect one plant host; other pathogens have wide host ranges and can infect several plant hosts in the same family or many plant hosts across different families. A larger inoculum load—when environmental conditions are favorable and a susceptible host is present—can cause significantly higher levels of disease than a smaller inoculum load in the same conditions. Over time, if a susceptible crop is not planted, inoculum levels may decrease as the pathogen decomposes or dies due to the absence of a susceptible host. A 3-year crop rotation is recommended for most soilborne pathogens. This means, for example, that if tomatoes, a solanaceous crop, are planted in a field in year 1, tomatoes or other solanaceous crops (e.g., peppers, eggplants, potatoes) should not be planted again in that field until year 4. Crop rotation recommendations may be even longer (7 years) if a pathogen is able to better survive in the soil in the absence of a susceptible host.

Cage, stake, or trellis plants. Often, tomato fruits become infected when they come in contact with pathogens in the soil or when infested soil is splashed onto low-hanging fruit. Caging, staking, or trellising plants can help create space between susceptible fruits and potential pathogens in the soil. Caging, staking, and trellising also help plants remain upright and can make it easier for sunlight and wind, which help reduce leaf wetness, to pass through plant canopies.

Use mulch. Organic or plastic mulch around tomato plants can help reduce the incidence of some diseases. The mulch acts as a physical barrier and can help prevent pathogens in the soil from being splashed or blown onto susceptible plant parts (stems, leaves, fruits). Additionally, some reflective mulches repel insect vectors that are known to transmit tomato viruses.

Avoid working with wet plants. Wait until water from dew, precipitation, or irrigation has dried from plant surfaces before moving through and working with a crop. This reduces the possibility of spreading bacteria and fungi from infected to noninfected plants.

Avoid "dirtying" plants during cultivation. Piling or throwing soil against or onto plants can increase the chance of disease development. Piling soil against plant stems can create conditions favorable for fungal growth and stem rots. Throwing soil against plant tissues increases the possibility of pathogens present in the soil coming into contact with susceptible tissues.

Wrap stems before planting. In areas where southern blight may be a problem, aluminum foil can be used to wrap tomato stems before planting. The foil provides a physical barrier between the stem and the southern blight fungus in the soil. The foil should extend at least 2 inches above and below the soil line and should be loose enough to allow room for future plant growth. This practice is generally only feasible for small home garden plantings.

Avoid using tobacco. *Tobacco mosaic virus* can be present in tobacco products and can easily be transmitted to susceptible tomato varieties by workers who use tobacco products and then begin working with plants without properly washing or disinfecting their hands.

Sanitation

Use disease-free seeds and plants. Purchase seeds and transplants from reputable sources. Seeds certified to

be free of certain diseases are available from various seed companies. Do not save seeds from tomatoes that were diseased or that were grown in fields with disease.
If producing your own transplants, plant seeds in sterile growth medium in trays that are new or, if you choose to reuse trays, that have been disinfested. Disease can spread rapidly in plants growing closely together, such as in a transplant tray. Since disease symptoms do not develop immediately, it may be best to avoid using plants grown in the same transplant tray as transplants that are showing symptoms of disease.

When purchasing plants from local nurseries or garden stores, only purchase plants that do not show symptoms of disease. Plants that begin to show symptoms of disease before planting in the field or greenhouse should be discarded.

Use effective seed treatments to treat seeds. Seed treatments that use hot water or various chemicals have been shown to be effective at reducing various diseases caused by bacteria, fungi, and viruses. Procedures for various seed treatments can be found in the most recent edition of the Southeastern U.S. Vegetable Crop Handbook. Because seeds may be damaged by treatment, a sample of the seed you intend to treat should be treated and tested for germination before treating the entire seed lot.

Remove diseased plants or plant parts. Observe a crop regularly for signs and symptoms of disease. If disease is limited, infected tissue may be removed from individual plants, or individual plants may be completely removed. Plants that are heavily diseased should be removed entirely, including the roots. This is particularly true when plants have southern blight, bacterial wilt, and timber rot. If plants with these diseases are not removed, the pathogen could continue to grow and reproduce on or within the plant, allowing the amount of inoculum to increase. Plants suspected of having a virus should be removed and destroyed immediately.

When roguing a plant from a field or garden, it is a good idea to bring a garbage bag to the site of the plant to be rogued to immediately contain the infected plant. This can help reduce the possibility of widespread contamination that might occur when carrying an infected plant throughout the field or garden. This practice can also be useful when removing various infected plant parts from plants.

Destroy, bury, or remove crop debris. Many tomato pathogens can survive through the growing season or through the winter on plant debris left in the field or an enclosed structure or in a cull or debris pile near a planting site. These pathogens may continue to grow and produce inoculum on the debris, and they could be transferred to healthy plants by wind, water, insects, or human activity. Thus, properly destroying and removing plant debris from a planting site can help to reduce the inoculum available for new infections. In some cases, such as with southern blight, deep-plowing crop debris to a depth of at least 6 inches helps bury sclerotia or other inocula and speeds up decay of these organisms, thereby reducing the amount of inocula that may be available to cause disease in future crops.

If possible, avoid placing diseased plant debris into compost heaps. If proper composting conditions are not met, pathogens may not be killed and could be introduced into planting sites through the spread of infested compost.

Clean and disinfest plant-support structures, tools, containers, and equipment. Some plant pathogens can survive on plant-support structures, tools, containers, and equipment between uses and seasons. These pathogens can be spread or introduced into new areas when these ***infested*** items are used in fields or on plants that do not have disease. For these reasons, it is very important to regularly clean and ***disinfest*** items that are used in plant production.

Some pathogens, once established in a field, are very difficult or impossible to eradicate. Equipment should be cleaned to remove all soil and plant debris before being moved to another field. This can help prevent the movement of pathogens from infected or infested fields to noninfected or noninfested fields.

Between crops, containers and plant-support structures should be cleaned to remove soil and plant debris and then disinfested with a suitable disinfectant. This practice can help to prevent the carryover of pathogens from season to season. Tools, such as pruning shears, should be cleaned and disinfested *often* throughout the growing season. Some pathogens can be spread very easily from infected plants to noninfected plants on tools, particularly when those tools are used to create wounds, which are necessary for some pathogens to gain entry into a plant. Disinfestation of pruning shears in between

uses on individual plants can help prevent the spread of these pathogens. A number of disinfectants are available for tools, equipment, and surfaces. A list of some available disinfectants, as well as advantages and disadvantages of each, is provided in MSU Extension Information Sheet 1955 *Choosing a Disinfectant for Tools and Surfaces in Horticultural Operations*.

Control weeds. Some weeds are hosts of certain pathogens that can infect tomatoes and can serve as sources of inoculum that can be easily spread to tomatoes. These weeds may also serve as hosts of certain insect vectors that can feed on and transmit tomato viruses. Insect vectors can feed on infected weeds, pick up virus particles, and carry them to noninfected tomato plants. Even if weeds are not infected, they may attract insect vectors closer to tomato plantings and may enable the buildup of larger insect vector populations that could transmit viruses between infected and noninfected tomato plants.

Chemical Management

Apply fungicides that are effective against target diseases. Fungicides can successfully manage many tomato diseases in commercial tomato production and home gardens. Fungicides are most effective when applied before disease develops and should be used as part of an integrated pest management (IPM) program. It is usually necessary to make regular applications of fungicides as long as the target pathogen is present and environmental conditions are favorable for disease development.

Because some pathogens can quickly develop resistance to fungicides, resistance management strategies should be used. Rotating (alternating) fungicides is the most commonly used method of resistance management. Each fungicide uses a specific biochemical mode of action to attack a pathogen. 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, 21, 27). Rotation of fungicides should be based on the FRAC codes (groups), provided on the product label, rather than by the product name or the active ingredient of a fungicide because different products may use the same active ingredient or related active ingredients that have the same mode of action.

Fungicide rotation is easier to carry out in commercial tomato production because fungicides from a larger number of FRAC groups are available for commercial producers. A list of fungicides labeled for use against various diseases in tomatoes grown for commercial production as well as an efficacy table of those fungicides against certain diseases can be found in the latest edition of the *Southeastern U.S. Vegetable Crop Handbook*. Please be aware that not all products are registered for use in every state. To determine if a product is registered for use in Mississippi, you can visit one of the online pesticide label databases that provides state registration information. An example of an online pesticide label database is Kelly Registration Systems (***www.kellysolutions.com***), which includes a pesticide registration search feature. Kelly Registration Systems works with the Mississippi Department of Agriculture to provide product registration information. A list of other pesticide label databases can be found in MSU Extension Publication 3155 *Pesticide Label Databases*.

Homeowners do not have access to the variety of fungicides that are used to manage diseases in commercial tomato production. However, various trade name products containing the fungicides chlorothalonil, copper, mancozeb, myclobutanil, and phosphorous acid are labeled for various tomato diseases and are available at local garden stores (**Table 1**). These products can be used to manage the labeled diseases of tomatoes in home gardens. Chlorothalonil and mancozeb have multiple modes of action against a pathogen; thus, there is a decreased risk of pathogens developing resistance to these fungicides. Coppers also have multiple modes of action against a pathogen; however, resistance to some bacterial pathogens in tomatoes has been reported. Use caution when applying copper fungicides. Application during temperatures around or greater than 90°F or before 3 or more days of overcast, rainy weather can burn plant tissue (cause phytotoxicity).

Table 1. Fungicides* labeled for tomato diseases that are available for homeowner use in Mississippi.

Active Ingredient (FRAC Group)	Trade Products [PHI**]	Labeled Diseases
chlorothalonil (FRAC M5)	Bonide Fung-onil Multi-purpose Fungicide Concentrate[1] [0] Bonide Fung-onil Multi-purpose Fungicide Ready to Use[2] [0] Ferti-lome Broad Spectrum Landscape & Garden Fungicide[3] [0] Ferti-lome Broad Spectrum Landscape & Garden Fungicide Ready to Use[4] [7] GardenTech Daconil Fungicide Concentrate[5] [0] GardenTech Daconil Fungicide Ready to Use[6] [0] Hi-Yield Vegetable, Flower, and Ornamental Fungicide[7] [0] Ortho MAX Garden Disease Control[8] [0] Southern Ag Liquid Ornamental and Vegetable Fungicide[9]	anthracnose[1-6,8,9], Alternaria fruit rot (black mold) [1-6,8,9], Botrytis gray mold[1-6,8,9], early blight[1-9], gray leaf mold[1-9], gray leaf spot[1-9], late blight[1-9], Rhizoctonia fruit rot[1-6,8,9], Septoria leaf spot[1-9], and target spot[1,3,7,9]
copper (various) (FRAC M1)	Bonide Copper Fungicide Spray or Dust Ready to Use[1] Bonide Liquid Copper Fungicide Concentrate[2] Bonide Liquid Copper Fungicide Ready to Use[3] Monterey Liqui-Cop[4] Natural Guard Copper Soap Fungicide Concentrate[5] ***Natural Guard Copper Soap Fungicide Ready to Use[6] Southern Ag Liquid Copper Fungicide[7]	Anthracnose[1-3,5-6], bacterial speck[1-7], bacterial spot[1-7], early blight[1-7], gray leaf mold[1,2], gray leaf spot[1], gray mold[2-3,5-6], late blight[2-7], leaf mold[2-3,5-6], Septoria leaf spot[1-3,5-6], and Stemphylium leaf mold[1]
mancozeb (FRAC M3)	Bonide Mancozeb Flowable with Zinc[1] [5] Southern Ag Dithane M-45[2] [5]	anthracnose[1,2], early blight[1,2], gray leaf spot[1,2], late blight[1,2], leaf mold[1,2], and Septoria leaf spot[1,2] bacterial speck[2] and bacterial spot[2] (when used in a tank- mix with fixed copper fungicide)
myclobutanil (FRAC 3)	Ferti-lome F-Stop Lawn & Garden Fungicide [0] Ferti-lome F-Stop Lawn & Garden Fungicide Ready to Spray [0] Monterey Fungi-Max [0] Spectracide Immunox Multi-purpose Fungicide Concentrate [0]	powdery mildew
phosphorous acid (FRAC 33)	Monterey Agri-Fos Systemic Monterey Garden Phos	late blight (*Phytophthora infestans*) and root rot (*Phytophthora* spp.)

*Only single-ingredient active ingredient products that are registered for use in Mississippi are listed. Combination products that include active ingredients effective against insects and/or mites are not listed, but these are also available.
**The preharvest interval (PHI) is provided when listed on the product label.
***OMRI-listed.

A large number of products, including various biologicals, biorationals, some coppers and bicarbonates, and neem oils, have been approved for use in organic production and are labeled for use against various tomato diseases. Other products approved for organic production may also be available. Many products approved for use in organic production have been approved by the Organic Materials Review Institute (OMRI); these products often display an "OMRI-listed" logo on the label. You can search the database at the OMRI website (***www.omri.org***) to determine if a product is OMRI-approved for organic use. Always check with your organic certifier if there is any question about a product being used in a certified organic operation. Organic products are most effective before the onset of disease and may not provide adequate protection once disease pressure is high.

Apply insecticides to control vectors. A number of insects, including whiteflies and thrips, can transmit (vector) viruses in tomatoes. In virus-susceptible cultivars, disease management often relies on control of the insects that can transmit the virus since plants that become infected with a virus cannot be cured. Insecticide applications can be useful in controlling *some* vectors. In some cases, however, insecticide applications are not very effective in reducing virus spread. For example, insecticide applications for thrips are not very effective at reducing TSWV, but the use of reflective mulches for thrips is effective at reducing TSWV.

When using fungicides and insecticides, remember: ***the label is the law.*** You must always completely read product labels before use and strictly follow the label.

REFERENCE

Jones, J. B., Zitter, T. A., Momol, T. M., and Miller, S. A. (eds). 1996. Compendium of Tomato Diseases and Pests, 2nd edition. American Phytopathological Society Press, St. Paul, MN. 168 pages.

ADDITIONAL RESOURCES

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

Greenhouse Tomatoes: Pest Management in Mississippi (P1861),
http://extension.msstate.edu/publications/publications/greenhouse-tomatoes-pest-management-mississippi

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

Organic Materials Review Institute (OMRI) website, ***https://www.omri.org***

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

Pesticide Label Databases (P3155),
http://extension.msstate.edu/publications/publications/pesticide-label-databases

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

Southeastern U.S. Vegetable Crop Handbook, available at ***https://www.greenbook.net/ResourceCenter/ProduceProductionGuides*** or by contacting your local county Extension office.

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

The Plant Doctor – Tobacco Mosaic Virus (IS1665),
http://extension.msstate.edu/publications/information-sheets/the-plant-doctor-tobacco-mosaic-virus

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

GLOSSARY OF PLANT PATHOLOGY TERMS

blight – a type of *symptom*; extensive damage (discoloration, development of lesions, wilting) or destruction of plant tissues that occurs rapidly

canker – a type of *symptom*; defined, dry, necrotic *lesion*

chlorosis (adj. chlorotic) – a type of *symptom*; the yellow discoloration of normally green tissues

diagnosis – the accurate identification of the cause of a *disease*

disease – an abnormality in a plant caused by infection with a biotic (living) agent

disinfectant – an agent, commonly a natural or synthetic chemical, that is used to kill *pathogens* on nonliving objects

disinfest – to kill *pathogens* present in the soil or on nonliving objects, such as tools and plant support structures, commonly with a *disinfectant*

disorder – an abnormality in a plant caused by an abiotic (nonliving) factor

hypha (pl. hyphae) – thread-like structures that make up the "body" of some fungi

infect – to form a parasitic relationship with a host plant

infested – to be contaminated with a *pathogen*

inoculum (pl. inocula) – any part of a pathogen that is capable of infecting a plant; examples: bacterial cell, fungal spore, *mycelium*, *sclerotium*

lesion – a type of *symptom*; localized areas of diseased tissue

mycelium – an example of a *sign*; a visible mat of fungal *hyphae*

necrosis (adj. necrotic) – death of plant tissue

nematode – microscopic roundworms; some are pathogenic to plants

oomycete – a fungus-like organism commonly referred to as a water mold

pathogen – a *disease*-causing organism/agent; common groups of *pathogens* include bacteria, fungi, *nematodes*, *oomycetes*, and viruses

race – a subgroup within a species separated from other subgroups by certain differences

sign – an indication of *disease*; the physical presence of a *pathogen*; examples: fungal *mycelium*, *sclerotia*, bacterial streaming

sclerotium (pl. sclerotia) – an example of a *sign*; fungal survival structure made up of a compact mass of *hyphae*

symptom – an indication of *disease*; the plant's reaction to infection by a *pathogen*; examples: *chlorosis*, wilting, *lesions*

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