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An Overview of Wilt Diseases of Tomato

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Abstract
Wilt diseases of tomatoes can be caused by fungal, bacterial, viral, and nematode pathogens, as well as by abiotic factors. Determining which agent is responsible can be vital for prescribing the proper management strategies. This publication discusses the common wilt diseases afflicting tomatoes in Alabama and the organisms and conditions that are responsible for their development. The publication describes the external and internal symptoms produced on the host by each pathogen; provides information on the disease life cycle and environmental conditions that favor disease development; and also provides diagnostic techniques that can be used to make in-the-field diagnosis of each disease described.

Keywords
wilt disese, fungal, bacterial, viral, nematode

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INTRODUTION
Tomato (*Lycopersicon esculentum* Mill.) is one of economically the most important vegetable crops in Serbia where it is grown both, indoors and outdoors on an area of about 20,000 ha in total. A number of economically important tomato diseases caused by fungi are transmitted by seed or transplants [1]. Tomatoes are parasitized by a number of pathogens, including *Fusarium oxysporum* Schlecht. f. sp. *lycopersici* (Sacc.) W.C. Snyder et H.N. Hansen, the causal agent of fusarium wilt of tomato [2] which is one of the most important species as tomato pathogen [3, 4 & 5]. In an indoor environment due to high temperature and humidity, *F. oxysporum* f. sp. *lycopersici* can cause significant damage.

The causal agent of fusarium wilt is soil borne pathogen which can persist many years in the soil without a host. Most infections originate from the population associated with infected tomato debris. Healthy plants can become infected by *F. oxysporum* if the soil in which they are growing is infested with the pathogen [6 & 7] However, pathogenic fungi of the genus *Fusarium* that are the causal agents of tomato wilt cause root and basal stem deterioration and result in the wilting of vegetable plants.

There are many possible causes of wilting of tomato plants. Successful treatment of the problem depends on accurate diagnosis and appropriate preventive measures. Some of the major causes of wilting are discussed below.

Wilt diseases of tomatoes can be caused by fungal, bacterial, viral, and nematode pathogens, as well as by abiotic factors. Determining which agent is responsible can be vital for prescribing the proper management strategies. This publication discusses the common wilt diseases afflicting tomatoes in Alabama and the organisms and conditions that are responsible for their development. The publication

describes the external and internal symptoms produced on the host by each pathogen; provides information on the disease life cycle and environmental conditions that favor disease development; and also provides diagnostic techniques that can be used to make in-the-field diagnosis of each disease described.

Fusarium wilt or "yellows" of tomato

Fusarium wilt, caused by the soilborne fungus *Fusarium oxysporum* f. sp. *lycopersici*, was formerly the most prevalent and damaging disease of both field and greenhouse tomatoes in Illinois, especially in the southern half of the state. Only the cultivated tomato (*Lycopersicon esculentum*), certain wild species of *Lycopersicon*, and eggplant are affected. The fungus, however, can colonize the roots of a number of weeds. Illinois now has over 4,000 acres of Fusarium-wiltinfested soil. If suitable resistant or immune varieties were not widely available, wilt would undoubtedly be the most damaging disease of tomatoes in this state. The Fusarium fungus is present in all important tomatogrowing regions of the world. It is most damaging in the southern United States and in northern states during excessively hot, dry seasons.

Symptoms

Tomato plant susceptible to Fusarium wilt

The first symptom of Fusarium wilt in gardens and fields is usually the golden yellowing of a single leaflet or shoot, or a slight wilting and drooping of the lower leaves on a single stem. As the fungus develops inside the stem, plants show progressive yellowing, wilting, and withering starting generally with the lowermost foliage (e.g., Figure 1). Yellowed and wilted leaflets drop early. Often the symptoms appear first only on one side of the stem. Affected plants turn a bright yellow, wilt, dry up, and usually die before maturity, producing few, if any, fruit.

When the epidermis and cortical tissues (bark) on a section of the main stem close to the base of the plant is cut and peeled back, a distinct chocolate-brown discoloration of the water- and food-conducting (vascular) tissue is evident. The streaks extend from the roots up through the branches and into the petioles.

Symptoms of Fusarium wilt may be confused with those of Verticillium wilt, caused by a common soil fungus *Verticillium albo-atrum (V. Dahliae).* The two tomato wilts usually cannot be distinguished except by culturing the fungus in the laboratory. The Verticillium fungus, unlike Fusarium, also attacks brambles, eggplant, okra, pepper, potato, strawberries, and 300 or more other herbaceous and woody plants. The Verticillium fungus thrives best in cool, moist soil (60° to 75°F or 15° to 23°C), and this wilt is therefore more serious in the northern half of Illinois in most seasons. Control measures are the same as those given below for Fusarium wilt.

Control

1. Plant only certified, disease-free seed and transplants in fertile, well-drained, wilt-free soil. Tomato seed treated properly with hot water is free of the Fusarium fungus.
2. Disinfest greenhouse and seedbed soil before planting, using steam or a soil fumigant (e.g., chloropicrin, Vorlex, methyl bromide, etc.) that is effective against soilborne fungi. Greenhouse structures, benches, containers, used stakes, and tools should be disinfested and pathogen-free.
3. In infested soil, grow only tomato varieties that are highly resistant or immune to Fusarium and Verticillium wilts (labeled VFN) and suitable for growing in Illinois. For information on resistant varieties see Illinois Circular 1373, Midwest Vegetable Production Guide for Commercial Growers and C1354, Illinois Homeowners' Guide to Pest Management. Also consult current seed catalogs and trade publications. Practically all of the newer tomato varieties are resistant to race 1 and many are also resistant to race 2. When seed catalogs report resistance to Fusarium wilt without reference to race, the resistance is to race 1. Race 2 resistance is usually specified as such when present. We suggest that race 2-resistant varieties be grown only where it is needed. This will minimize selection pressure for development of race 2. No commercial tomato varieties are known to be resistant to the new race reported in Florida.
4. Grow tomatoes in the same field area no more than once in four years. Lightly infested soil may become heavily infested by too-frequent cropping of tomatoes.
5. In home gardens, pull up and burn wilt-infested plants when they become severely diseased.
6. Spraying or dusting–useful in controlling tomato blights, leaf spots, and fruit rots–is not effective in controlling Fusarium wilt. [8]

Verticillium Wilt

Symptoms of Verticillium wilt, caused by the soilborne fungus Verticillium albo-atrum, may be confused with those of Fusarium wilt. The two fungal wilts cause similar field symptoms and cannot be distinguished except by growing the fungus in the laboratory. Verticillium, unlike Fusarium, also attacks brambles, eggplant, okra, pepper, potato, strawberries, and 300 or more other herbaceous and woody plants. The Verticillium fungus thrives best in cool, moist soil (60 degrees to 75 degrees F) and therefore is not as common as Fusarium in Alabama. Control measures for Verticillium wilt are the same as those for Fusarium wilt.

Symptoms

In spite of the name verticillium wilt, a true wilt seldom occurs in tomato, at least not until late in the season. Rather, under good conditions of moisture and nutrition, yellow blotches on the lower leaves may be the first symptoms, then brown veins appear, and finally chocolate brown dead spots. The spots may be confused with alternaria early blight, but they are not definite, nor do they develop concentric bull's-eye rings.

The leaves may wilt, die, and drop off. The disease symptoms progress up the stem, and the plant becomes stunted. Only the top leaves stay green. Fruits remain small, develop yellow shoulders, and may sunburn beca use of loss of leaves.

Infection takes place directly when the fungus threads enter the root hairs. It is aided in its entrance if rootlets are broken or nematodes have fed on the root system. The fungus grows rapidly up the xylem, or sapconducting channels. Its activity there results in interference with the normal upward movement of water and nutrients. The fungus produces a toxin that contributes to the wilting and spotting of the leaves. Diagnosis involves making a vertical slice of the main stem just above the soil line and observing a brown color in the conducting tissues under the bark. This discoloration can be traced upwards as well as downwards into the roots. In contrast to fusarium wilt, verticillium wilt discoloration seldom extends more than 10-12 inches above the soil, even though its toxins may progress farther. The Causal Fungus Its wide host range permits Verlicillium to persist in soils for long periods. It remains alive by means of dark resting threads, which form in great numbers on dying diseased underground plant parts. It can attack and mUltiply in many common weeds, including ragweed, cocklebur, and velvet leaf. One form of the fungus produces tiny black resting bodies (microsclerotia), which help it survive over winter. The pathogen is sensitive to soil moisture and temperature. Tomatoes and potatoes must have at least a day of saturated soil before infection occurs. Soil temperatures must be modera te or cool for infection to take place: 75° F (24° C) is optimum with 55° F(13° C)minimumand86° F (30° C) maximum.

Control

Long rotations (4-5 years) with nonrelated crops, well-drained soils, and soil moisture kept at the minimum for good growth are advisable. In greenhouses or with plastic-strip mulch, soil fumigation gives good control and is feasible on high-value crops. By far the most feasible and economic control is the use of Verticillium-tolerant tomato cultivars of which there are many with varying maturities and excellent horticultural qualities.

Southern Blight

Southern blight, also known as white mold and stem rot, is caused by the soil-borne fungus *Sclerotium rolfsii*. The disease is a common problem on vegetables, especially tomatoes, as well as most other broadleaf crops such as peanut and soybean. Plants of any age can be attacked if environmental conditions are suitable. Development of southern blight is favored by moist conditions and high temperatures (more than 85 degrees F).

Generally, the first above-ground symptoms are leaf yellowing and wilting of infected plants. The stem at the soil line often appears soft and sunken (cankered) and develops a brown to black discoloration both internally and externally. Under moist conditions, a white fungal growth can be seen on the lower stem near the soil surface on fruit in contact with the soil; and on crop debris on the soil around the base of the plant. Spherical, light brown, mustard-seed size (1 to 2 mm) sclerotia often form in the mycelium. Under dry conditions, fungal mycelium and sclerotia may not be visible. However, if southern blight is suspected, placing a section of the lower stem and a moistened paper towel in an enclosed plastic bag for 24 hours will stimulate formation of a white mat of fungal growth. This would be diagnostic for southern blight.

Symptoms

Young infected plants wilt suddenly and permanently. On older plants, symptoms first appear as a dark brown lesion on the stem near the soil surface. The lesion girdles the stem, causing leaf yellowing and wilting. White mats of fungal growth are produced on the stem and nearby in the soil on any organic debris. Wilting in infected plants may be more evident when soils begin to dry out. After a few days, mustard seed-sized (0.5 mm diameter), round, tan to dark brown overwintering structures known as sclerotia appear on the white fungalgrowth. The abundant sclerotia that form on the outside of the

stem tissue are a good diagnostic feature. They are round, soft, and smaller in diameter, and lighter in color than those caused by another fungus, Sclerotinia sclerotiorum, which also causes a disease in tomato. The sclerotia of the latter are found inside tomato stem tissue.

Control

Crop rotation has a strong influence on survival of the fungus. Grow tomato after non-host crops such as maize, sorghum, small grains, or cotton. Allow ample time for breakdown of green manure before planting the tomato crop.

Bury crop debris to a depth of 24 cm. Eradicate weeds, avoid dense planting, and choose fields that are well drained, rich in humus, and not too acidic. Plastic mulch may shield the branches and fruit from sclerotia. Disease levels have been reduced by application of ammonium nitrate either before planting or as three side dressings at monthly intervals while the crop is growing. Efforts are being made to develop solarization and biological control practices. Soil fungicides offer some protection. Consult with your local extension agent to determine the fungicides that may be available in your region.

Bacterial Wilt

Bacterial wilt is caused by the soil-borne bacterium *Pseuclomonas solanacearum*. A characteristic of this disease, which sets it apart from other wilt diseases, is that plants wilt and die rapidly without the presence of yellowing or spotting of the foliage. The disease can occur in newly cleared land as well as in areas where susceptible crops have not been grown previously. The bacterium often enters a field on infested transplants, equipment, or through drainage water. The pathogen can overwinter in soil. Bacteria infect plants through the roots or stem, most often where tissue has been injured by cultivating, or by some other physical means such as nematodes. Bacteria invade the vascular tissue, apparently causing wilt by a gradual blocking of the water conducting vessels. The disease is most commonly found in low, wet areas of fields and is most active at temperatures above 75 degrees F.

To identify bacterial wilt, cut and peal back a section of the epidermis and cortical tissue (bark) just above the soil line. The center of the stem (pith) will, in early stages, appear water soaked; later, the pith will turn brown and sometimes become hollow he discoloration of the pith distinguishes this disease from Fusarium and Verticillium wilt. Another relatively easy diagnostic technique is to cut a portion of the affected stem and place in it a clear glass container filled with water. The appearance of a white, milky ooze streaming out of the cut end of the discolored vascular tissue is diagnostic for this disease. Bacterial wilt attacks members of the Solanaceous plant family, which includes peppers, potatoes, and eggplant, making crop rotation an effective method of control. Growing susceptible crops in the same area no more than once every 4 years will reduce inoculum in the soil. Soil fumigation should be considered in heavily infested fields. Roguing of wilted plants and the soil surrounding their roots can reduce spread of the disease and may be a viable control alternative in home garden situations. Soil solarization is another alternative for control of bacterial wilt (see Extension publication ANR-0713, “Soil Solarization for the Control of Nematodes and Soil-borne Diseases”).

Symptoms and signs

At the early stages of disease, the first visible symptoms of bacterial wilt are usually seen on the foliage of plants. These symptoms consist of wilting of the youngest leaves at the ends of the branches during the hottest part of the day

In young tomato stems, infected vascular bundles may become visible as long, narrow, dark brown streaks. In young, succulent plants of highly susceptible varieties, collapse of the stem may also be observed

In well-established infections, cross-sections of stems may reveal brown discoloration of infected tissues

Symptom expression is favored by high temperatures (85-95°F / 29-35°C) and symptoms of the disease may progress rapidly after infection. However, under favorable conditions, symptomless plants may remain latently infected for extended periods of time. After infection the pathogen may survive in and be spread from the infected plant.

A common sign of bacterial wilt of tomato observed at the surface of freshly cut sections from severely infected stems is a sticky, milky white exudate, which indicates the presence of dense masses of bacterial cells in infected vascular bundles, and particularly in the xylem.

Control

Bacterial wilt of tomato is difficult to control, and no single strategy has shown 100% efficiency in control of the disease so far.

Bactericides (copper) and antibiotics (streptomycin, ampicillin, tetracycline and penicillin) have shown little efficiency on suppression of *R. solanacearum* in the field and are environmentally destructive and fairly expensive to apply. As a result, a combination of diverse control methods, including **host resistance**, **cultural practices**, and the use of **chemical or biological control** should be used in an

integrated pest management approach to control bacterial wilt of tomato in locations where the pathogen is established.

Chemical control by soil fumigation (chloropicrin) or application of phosphorous acid is also expensive to apply; soil fumigation has been reported to achieve limited success if combined with other control methods. When used, chemical control should be integrated with other methods to reduce selection pressure for pathogen resistance.

Biological control, based on use of *R. solanacearum* antagonists, and use of suppressive soils has shown promising results at the small experimental scale, but still needs to be validated at a larger scale.[9]

Bacterial Canker

Bacterial canker, caused by *Clavibacter michiganensis* subs. *michiganensis*, is a recurrent and serious problem on tomatoes. Bacteria survive from season to season in infested crop debris, on wooden stakes and other equipment, as well as in other Solanaceous hosts such as black and perennial nightshade and ground cherry. The fungus is commonly introduced into a field on infected transplants or seed. Its spread within the field occurs through wounds during irrigation or by splashing rain.

Weeks may pass between the time of infection and the development of symptoms. Vascular infections cause wilting, chlorosis, and eventual death of the plant. If the stem is cut open longitudinally, a yellow to reddish-brown discoloration may be observed in the vascular tissue. In later stages, canker lesions may develop on the stem, petioles, and underside of the foliage Superficial foliar infections cause necrosis of the foliage, usually from the leaf margins inward, which can advance until the entire leaf and petiole dies. Early infection of the fruit can result in development of “bird’s-eye” spots, which are characteristically white, necrotic lesions about inch in diameter that soon develop dark centers surrounded by a white halo.

Symptoms

Bird's eye spot of bacterial canker.

Tomato plants of all ages are susceptible to bacterial canker; all above-ground parts are susceptible. Symptoms on seedlings include small, water-soaked lesions on foliage; stunting; and wilting. Seedlings affected by bacterial canker will die in many cases.

Wilting is also evident in field plants and is often the first symptom to be observed . Infected stems split, resulting in the open cankers that give this disease its name. When cut lengthwise, diseased stems show a reddish-brown discoloration of the vascular system. The pith may be discolored and grainy (mealy) or pitted. Wilting and vascular discoloration are indicative of a systemic infection of the tomato plant.

Control

Control of bacterial canker can be difficult once symptoms are observed. A preventive disease management program is the best defense [10]

Tomato Pith Necrosis

Tomato pith necrosis, caused by the soil-borne bacterium *Pseudomonas corrugata*, is a disease sometimes confused with bacterial canker. The bacterium is considered a weak pathogen on tomatoes growing too rapidly. Affected plants are randomly scattered in the field. Initial symptoms include yellowing of young leaves, which may progress into yellowing and wilting of the top part of the plant. Black streaking may be apparent on the main stem, which often splits. When the stem is cut open longitudinally the center of the stem (pith) will be hollow and often has a chambered (ladder-like) appearance. Profuse development of adventitious roots can be associated with the affected pith areas and the stem may appear swollen. Plants affected with pith necrosis do not exhibit the marginal necrosis of leaflets nor the bird's-eye spotting of the fruit characteristic of bacterial canker. Plants may die if the lower stem is affected, however, the disease usually does not progress, and plants will outgrow the condition.

High nitrogen fertilization, cool night temperatures, high relative humidity, and plastic mulches all increase incidence and severity of pith necrosis. The disease frequently occurs when the first fruit set is close to mature green. Control requires avoiding excessive nitrogen rates.Tomato pith necrosis, caused by the soil-borne bacterium *Pseudomonas corrugata*, is a disease sometimes confused with bacterial canker. The bacterium is considered a weak pathogen on tomatoes growing too rapidly. Affected plants are randomly scattered in the field. Initial symptoms include yellowing of young leaves, which may progress into yellowing and wilting of the top part of the plant. Black streaking may be apparent on the main stem, which often splits. When the stem is

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Control.

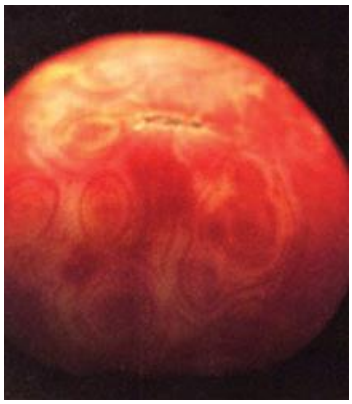
Tomato pith necrosis may be controlled by avoiding excessive nitrogen rates.[11]

Tomato Spotted Wilt Virus (TSWV)

Tomato spotted wilt is caused by a virus that is usually spread by thrips. Tomato plants infected with spotted wilt become stunted and often die. Initially, leaves in the terminal part of the plant stop growing, become distorted, and turn pale green. In young leaves, veins thicken and turn purple, causing theleaves to appear bronze. Necrotic spots, or ring spots, are frequently present on infected leaves and stems often have purplish-brown streaks. Fruit, infected with the virus, may exhibit numerous ringspots and blotches and may become distorted if infected when immature.

Currently, there is no effective way to control tomato spotted wilt. Control of TSWV-infected weeds adjacent to the field, where the virus can overwinter, should reduce the source of infection. Applying systemic insecticides to the soil at planting can slow the initial spread of the virus into the field. Applying foliar insecticides later in the season will help reduce the build-up of thrips within the field. Spraying weeds bordering the field with insecticides along with the tomato field will also suppress the thrips population and the spread of the virus. Roguing out infected plants as soon as symptoms appear will also reduce spread of the disease.

Symptoms



Tomato spotted wilt-infected fruit.

The distribution of infected plants in a field is typically scattered, with relatively few plants affected. However, extensive losses can occur, since spread can continue on tomatoes throughout the summer. Symptoms vary, but usually begin with a blighting of young (upper) leaves, beginning with purple or brown spots on the leaves. Its appearance in the upper part of the plant distinguishes TSWV from fungal leaf blights, which often begin on the lower leaves. Purple to bronze streaks and rings may appear on stems. In older infections, stem surfaces exhibit tan to brown, corky areas and tip dieback. Plants infected when small are stunted and pale, and leaves are rolled, exhibiting purple veins on the undersides. Infected, ripe fruit show noticeable yellow rings. Some fruit have a dark, rough, "alligator" skin.

Control

Reflective mulches help to control spotted wilt by causing fewer thrips to land on the tomato plants. Extensive research has shown the benefits of reflective mulches in reducing the incidence of the disease. Metalized mulches are sold for this purpose. Gardeners can produce reflective mulches by spraying black plastic with aluminum paint or by placing aluminum foil, shiny side up, on the ground around the plants.

Varieties with resistance to spotted wilt have recently become available, primarily for commercial growers (a deteminate saladette variety, "Health Kick," is provided by Park Seed Co. for the home garden market). The level of resistance in all varieties

with spotted wilt resistance is only intermediate, and other methods of control may be needed. Following are determinate, slicing varieties: Amelia, Bella Rosa, BHN 602, BHN 640, Camel, Crista, Finishline, Fletcher, Mountain Glory, Nico, Primo Red, Quincy, Red Bounty, Red Defender, and Talladega. Determinate, saladette varieties include: BHN 685, Health Kick, Monticello, Muriel, Patria, Plum Regal, Picus, and Tachi. Indeterminate saladette varieties are Reposado, Super Cromo, and UG 7901. BHN 1010 is a grape type.Many of these varieties have not yet been evaluated extensively and there is little information on their performance under our conditions.

Many authorities suggest that infected plants not be removed, as doing so may cause more movement of the thrips than would occur otherwise. Furthermore, TSWV-infected tomato plants sometimes grow out of the condition and produce normal fruit.

Insecticides with thrips activity have been shown to provide slight suppression of spotted wilt if applied early and frequently. Commercial growers who wish to follow such a program should apply Admire at planting and continue with foliar applications of dimethoate, Venom, Lannate, Monitor, Rimon, or Radiant. Home gardeners are more limited in their choices, but spinosad products such as Conserve (Southern Ag) and Ferti-lome Borer, Bagworm, Tent Caterpillar, and Leafminer Spray would be the most effective.Reflective

Root-Knot Nematodes

Root-knot nematode, *Meloidogyne* spp., can attack tomatoes as well as more than 2,000 other species of plants. Nearly forty species have been described and physiological races exist among many of them. When root-knot nematode populations are high, tomato plants often are stunted and yellowish (nitrogen deficiency symptoms) and may wilt during dry weather or during the hottest part of the day. Detecting root-knot nematodes in the field is easily done by examining the roots of symptomatic plants. The nematode causes knots or galls to develop on both large and small roots; knots range in size from the head of a pin to an inch in diameter.

Root-knot nematodes have a wide host range that includes many cultivated crops as well as many weed species. The nematodes survive in the soil from year to year and become active as soil temperatures increase in the spring. The most effective control of root-knot nematodes is through the use of resistant varieties. Also rotations with grasses and clean fallowing during the off-season will reduce nematode populations. Soil fumigation is an effective means of reducing damaging population levels temporarily (one growing season). Soil solarization has been shown to be effective in reducing nematode populations when environmental conditions are favorable for its use (see Extension publications ANR-0030, "Nematode Control in the Home Garden"; ANR-0500, *Alabama Pest Management Handbook*; and ANR-0713, "Soil Solarization for the Control of Nematodes and Soilborne Diseases").

Symptoms

Root galls of root-knot nematodes.

Aboveground symptoms Root-knot nematodes are usually first detected in localized areas within a field greenhouse, high-tunnel, nursery, or home garden. Gradually, the area of infected plants expands in size and the entire planting can eventually be affected. Aboveground symptoms usually involve stunting, chlorosis (yellowing) of lower leaves (nitrogen deficiency symptoms) and yield reductions that often worsen over time. Plants may wilt during the heat of the day, especially under dry conditions or in sandier soils. Since these symptoms can also be caused by a number of unfavorable growing conditions and other diseases, diagnosis of root-knot requires an examination of the root system or an inspection of the adjacent soil for nematodes.

Root symptoms Carefully dig up affected plants, shake soil from the root system, and look for swollen and distorted roots. Root-knot galls may vary in size and shapeon heavily infected plants, galls tend to fuse together so that large areas, or the entire root, may be swollen. Lateral roots appear on root crops (e.g. carrots) resulting in a condition known as hairy root. Infected potato tubers may have small, bumpy swellings on the surface.

Control

The management of plant-parasitic nematodes of tomato relies on integrated pest management (IPM), which is includes use of various cultural, biological, and chemicalstrategies. A reliable preplant sample estimates of the nematode population density and consequent potential for damage forms the basis for

selecting the appropriate management strategy. Cultural practices include a clean follow during the off-season, control of weeds and volunteer plants, destroying infected plants, avoiding use of contaminated water with nematode, and using nematode-free transplants. Wherever it is available, using resistant cultivars to minimize losses to root-knot nematodes is recommended. Chemical control of root-knot nematodes of tomatoes should be considered as a preplant practice because once root infection occurs and plant damage become visible, it is not possible to resolve the problem completely. As a preplant treatment, using a multi-purpose fumigation such as methyl bromide or Telone C35 to reduce root-knot nematode populations and soilborne disease pressure to avoid significant yield loss.

Leaf Roll

Leaf roll of tomatoes is caused by unfavorable environmental factors. High temperatures, prolonged periods of wet soil conditions, and drought may promote symptom development. Leaf roll is characterized by the upward curling of leaflets on older leaves. At first, leaflets appear to be cupped; this may progress until the margins of the leaflets touch or even overlap each other. Rolled leaves may feel firm and leathery. Symptoms may affect up to 75 percent of the foliage, although plant growth and fruit production are not altered significantly. Symptoms are most common when plants have a heavy fruit set. Controlling leaf roll is not a major concern since damage is minimal. Setting plants on well-drained soil and irrigating during periods of drought will help prevent the appearance of leaf roll. Leaf roll has been associated with varieties having a specific gene that favors this condition. Tobacco Mosaic Virus (TMV) can promote leaf roll symptoms on varieties containing this genetic makeup.

Symptoms and effects

Plants affected by tomato leaf roll suffer a greatly reduced growth rate and so become stunted or dwarfed. Leaflets are rolled upwards and inwards while the leaves are often bent downwards (epinasty) but are stiff rather than limp as in wilted plants. Leaves are thicker than normal and of a leathery texture and often have a purple tinge to the venation on the undersurface. The newly produced young leaves are paler in colour than those on healthy plants. Fruit, if produced at all on affected plants, is smaller than normal, dry in texture and unsaleable. Plants with an advanced infection will not produce fruit.

Control

No commercial varieties have been found that are resistant to tomato leaf roll. Commercially, plants are dusted or sprayed with insecticide but still may become infected with tomato leaf roll disease because the insect can transmit the virus before it is killed. Because there appears to be little if any secondary transmission from one tomato plant to another tomato plant, roguing (removal of affected plants) will not reduce the spread of the disease.

In the Middle East, inter-planting tomatoes with cucumbers was found to decrease the incidence of TYLCV infection in tomato crops because cucumbers are more attractive to whiteflies than tomatoes. Interplanting cucumbers or squash among the tomatoes could have a similar beneficial effect here in decreasing the incidence of TLCV-Au, which is transmitted by a whitefly in tomatoes, because TLCV-Au and TYLCV are somewhat related.

At present, the best thing to do to avoid large numbers of tomato leaf roll affected plants is to sow later in the season. For example, sowing in late March for planting in mid-April could be suitable, depending on the season.

Infectious Diseases of Tomato Fruit

Anthracnose

This is a fungal disease caused by *Colletotrichum coccoides* and occurs primarily on fruit. Leaf infections may also be found, but generally coincide with the occurrence of other leaf disorders such as another disease or physiological problems. In that sense, anthracnose is not an aggressive disease on foliage.

Considered the most damaging disease of fruit, anthracnose can infect green, immature tomatoes, however, the symptoms will not appear until the fruit ripens. Small, circular, indented dark spots will appear as the fruit changes to its mature color. The spot will expand to form concentric rings of dark specks which are the fruiting bodies of the fungus and contain spores. When conditions are moist, these fruiting bodies will exude large numbers of spores which may give the lesion a creamy-pink coloration. Infection will progress to the point where internal discoloration can be quite deep. Generally, the rot is localized and portions of the fruit can be eaten. In other cases, the disease will cause a predisposition of the fruit to other problems which accelerate the decay process.

The fungus survives the winter on diseased tomato vines, in the soil and in seeds. It also can become established on foliage infected by other pathogens late in the season. Spores are spread by splashing water and rain and infections are typical during times of warm weather in the '80s. Both green and ripe

tomatoes can become infected, yet symptoms may not develop until after ripening has occurred.

Early Blight

This disease was discussed above as related to foliage diseases. The fruit-infective stage commonly is associated with the stem end of the tomato. It is diagnosed by recognition of a series of concentric rings that give a distinguishing appearance to the lesion. Like anthracnose, the fruit can become infected at any stage of development, however, symptoms may not be noticeable until fruit ripening. While the disease is primarily found on tomato, other common vegetable crops like potato, pepper and eggplant can also serve as hosts.

Control of Fruit Diseases

Control measures for fruit diseases follow those outlined for diseases of foliage. The primary aim is to remove all infected debris from the garden because this is the source of initial infection. In addition, with fruit diseases, it is helpful to harvest at frequent intervals and pick all ripe fruit at each harvest so that the disease does not build up.

Non-infectious Disorders of Tomato Fruit

Blossom-end Rot

Blossom-end rot is a very common problem on green and ripe tomatoes appearing as a sunken brown to black circular spot on the blossom end of the fruit. Although there is little actual rot associated with the disorder, secondary organisms may invade the lesion and cause complete rotting of the fruit. The disorder is often associated with rapidly developing fruit during periods of hot, dry weather.

The main cause of blossom-end rot is a calcium deficiency of the soil, that is related to fluctuations in available moisture. Despite the fact that soils may have plenty of calcium available for uptake, moisture problems aggravate the deficiency. Addition of calcium will not solve the problem. A consistent supply of moisture can reduce the problem. Mulching will also help by stabilizing the moisture supply. If excessive levels of nitrogen are applied, blossom-end rot can be more serious. Also, staking and pruning may increase the incidence of the disorder. When fruits become affected, harvest them immediately so that other fruits will have a better chance of developing normally.

Fruit Cracking

Generally, there are two types of cracking which might be found on tomato fruit. With the first, radial cracks may appear coming out from the stem and running down the sides of the fruit. A second type of crack looks like concentric rings which encircle the fruit usually on the shoulders. In both cases, cracking is associated with rapid fruit development and wide fluctuations in moisture supply to the plant. If fruit has reached the stage of ripening during dry weather, the odds of developing some cracks will increase especially if heavy rains and high temperatures prevail during the ripening stage. In addition, often the condition is associated with specific varieties, like with blossom-end rot, mulching and avoidance of heavy nitrogen applications will lessen the chance of occurrence of this disorder.

Uneven Ripening

When fruit does not ripen evenly throughout and the normal red pigment is absent from localized areas, and then a condition of blotchy ripening is indicated. This disorder may appear as yellow to gray-green patches on the fruit. When sliced open a brown discoloration may be apparent. Cultural, weather and nutritional problems may contribute to the condition. Associated with this problem are low potassium levels, cloudy periods and inadequate light intensities. Other possible contributing factors are high soil moisture, high humidity, low temperature and soil compaction as well as excessive fertilization. All of these factors may promote a nutrient imbalance, which results in abnormal pigment formation. Beyond climatic conditions, provide balanced fertility and good cultural conditions to maintain plant vigor.

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