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Review Article

Fungal diseases on tomato plant under greenhouse condition

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ABSTRACT

The cultivation of crops in the greenhouse is the most intensive form of horticultural production. Greenhouse climatic conditions provide an ideal condition for the development of many foliar, stem and soil-borne plant diseases. Diseases are a major limiting factor for vegetable that cause serious yield reduction leading to severe economic losses. Fungi enter plants through natural openings such as stomata and through wounds caused by pruning, harvesting, hail, insects, other diseases, and mechanical damage. This chapter provides an overview of the most important diseases of tomato plants. Some of the diseases that will cover in this chapter are the follow: Early blight late, *Septoria* leaf spot, Late blight, *Fusarium* wilt, *Verticillium* wilt, Anthracnose, Buckeye rot, and Southern blight. For each disease, main symptoms and disease development are described. This review is based on combined information derived from available literature and expertise knowledge.

Keywords: Fungal diagnostic; Disease development.

1. EARLY BLIGHT

1.1. Introduction

Early blight is a common leaf-spotting fungal disease of tomato. It is also known as *Alternaria* leaf spot or target spot. Early blight, caused by the fungus *Alternaria solani* [1]. The early blight fungus can come from many sources. It can be in the soil, or on purchesed seeds or seedlings, and it can over-winter in the diseased debris of tomato plants and it can persist in the soil or debris for at least 1 year [2]. The fungus can survive winter's freezing temperatures and infect new plantings when foliage encounters contaminated dirt or dead plants. The fungus survives in the soil by forming resistant spores in association with diseased tomato debris capable of persisting for one year or more. Infection occurs rapidly under warm and humid conditions. Thousands of spores are produced in spots of infected leaves and are capable of causing more infections [3]. The fungal spores can be spread by wind and rain, irrigation, insects, workers, and on tools and equipment. Once the primary infections have occurred, they become the most important source of new spore production and are responsible for rapid disease spread. Early blight can develop quickly mid- to late season and is more severe when plants are stressed by nitrogen deficiency, drought,

or heavy fruit load. Early blight can affect almost all parts of the tomato plants, including the leaves, stems, and fruits. The plants may not die, but they will be weakened and will set fewer tomatoes than normal.

1.2. Symptoms

Premature loss of lower leaves is the most obvious symptom of the disease [4]. Infected leaves show brown to black spots (lesions) up to 1⁄2 inch diameter with dark edges and have a pattern of concentric rings resulting in the "target" appearance to the spot suggested by the common name (Figure 1) [5]. Later, spots frequently merge forming irregular blotches [6]. Defoliation progresses upward from the lower plant and infected leaves eventually turn brown and drop from the plant exposing the fruits to sun scald (Figure 2) [7]. Dark lesions on the stems start off small and slightly sunken. As they get larger, they elongate and you will start to see concentric markings like the spots on the leaves (Figure 3) [8]. Spots that form near ground level can cause some girdling of the stem or collar rot. Plants may survive, but they will not thrive or produce many tomatoes [9]. Early blight generally attacks older plants, but it can also occur on seedlings. If early blight gets on the seedlings, affected seedlings will have dark spots on their leaves and stems [10, 11].

Figure 1. Foliar symptoms of tomato early blight.

Figure 2. Defoliation caused by early blight on tomato plant.

Figure 3. Early blight of tomato stem.

They may even develop the disease on their cotyledon leaves. Basal girdling and death of seedlings may occur. This manifestation of the disease is called collar rot [12]. Early blight can infect plants at any stage during the growing season but usually progresses most rapidly after plants have set fruit (Figure 4) [13]. Green or red fruit may be infected by the fungus which invades at the point of attachment between the stem and fruit, and through growth cracks and wounds made by insects. Dark lesions enlarge in a concentric fashion and may affect large areas of the fruit. Mature lesions in fruit are typically covered by a black velvety mass of fungal spores.

Figure 4. Early blight rot symptoms on tomato fruit.

2. SEPTORIA LEAF SPOT

2.1. Introduction

Septoria leaf spot, also called *Septoria* blight, is caused by a fungus (*Septoria lycopersici*). It is one of the most common foliar disease of tomatoes. The disease is favored by warm temperatures 20-25°C and high relative humidity or the extended periods of leaf wetness caused by overhead irrigation, rain or heavy dews. Most infection probably arises from infested plant debris remaining in the soil from a previous tomato crop. *Septoria* leaf spot spreads rapidly and can quickly defoliate and weaken the plants, rendering them unable to bear fruit to maturity. The *Septoria* fungus lives on the fallen tomato plant debris and weeds that are on and in the soil. It is spread to the plants by both water and wind, usually splashing up on the plants from the soil.

2.2. Symptoms

Lower leaves are infected first, and the disease progresses upward and may also attack stems and blossoms, but rarely on fruit. Infection can occur at any stage of plant development but appears most frequently after plants have begun to set fruit. It first appears as small, water-soaked spots on the undersides of older leaves and the bottom of the plant that soon become circular spots about 1/16-1/8 inch in diameter (Figure 5) [14]. The lesions gradually develop grayish white centers with dark edges. The light-colored centers of these spots are the most distinctive symptom of *Septoria* leaf spot (Figure 6). When conditions are favorable, fungal fruiting bodies appear as tiny black specks in the centers of the spots [15]. These are fruiting structures that release spores. Spores are spread to new leaves by splashing rain. Heavily infected leaves turn yellow, wither, and eventually fall off. This will weaken the plant, send it into decline and cause sun scalding of the unprotected, exposed tomatoes. Defoliation progresses from the base of the plant upwards, and it can be severe after periods of prolonged warm and wet weather. Loss of foliage may cause fruits to become sunscalded. The *Septoria* defoliation resembles early blight disease. However, the larger dark leaf spots with concentric rings of early blight are clearly different from smaller *Septoria* leaf spots.

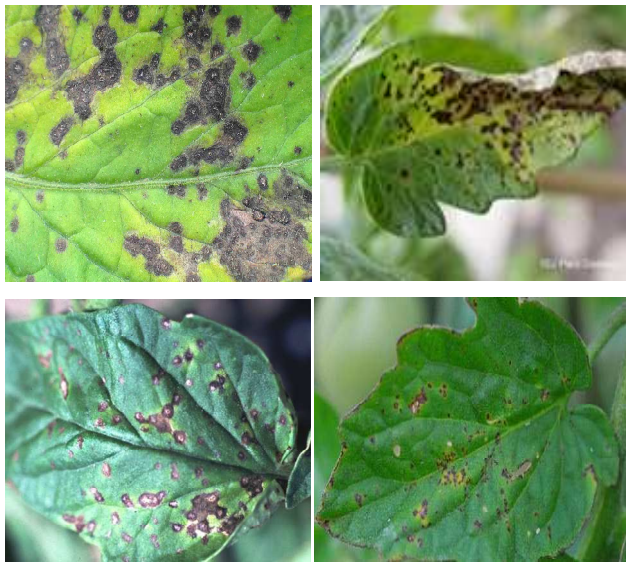

Figure 5. *Septoria* leaf spot symptoms on tomato plant.

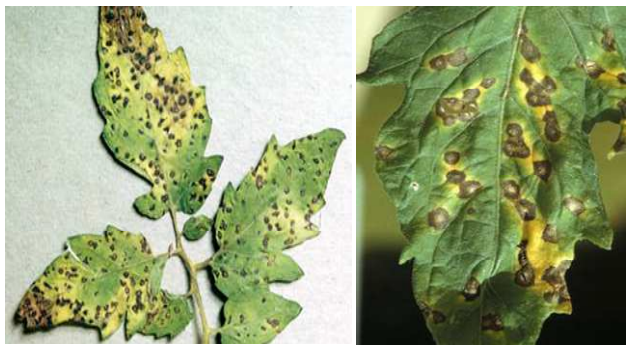

Figure 6. *Septoria* tomato leaf spot; the light-colored centers.

3. LATE BLIGHT

3.1. Introduction

Late blight is caused by the fungus *Phytophthora infestans and* usually appears in mid- or late August. The fungus is a wet weather disease favored by cool nights and warm days. Temperatures above 30°C are considered unfavorable for late blight development. The fungus survives mainly in potato seed tubers and in infected tomato transplants. Some survival may also occur in dead potato and tomato vines. The disease often begins in potato plants, from which spores of the fungus are blown by wind to infect tomatoes in favorable conditions. Disease development is rapid with extended periods of favorable conditions and ceases when weather becomes hot and dry. Usually, the warm to hot temperatures prevailing during periods of tomato production make the occurrence of this disease unlikely. However, the disease could be a potential problem during unseasonably cool and wet conditions on early-planted or fall-cropped tomatoes.

Figure 7. Late blight symptoms on tomato leaflet.

Figure 8. Brown streaks along the tomato stems caused by late blight.

3.2. Symptoms

All parts of the plant are affected and fruit decay can be severe. Late blight may infect either young (upper) or old (lower) leaves. It first appears as pale green water-soaked spots starting at leaf tips that enlarge rapidly, forming irregular, greenish black blotches (Figure 7) that expand rapidly when leaves are wet or humidity is high [13]. White mold usually develops at the margins of affected areas giving the plant a frost-damaged appearance. Entire plants may be rapidly defoliated when conditions favor the disease (Figure 7). If stems and petioles are infected, brown streaks along the stems will be presented and the areas above these infections wilt and die (Figure 8) [13]. Infection of green or ripe fruit produces large, irregularly shaped brown blotches that usually start at the stem (Figure 9). Infected fruits rapidly deteriorate into foul-smelling masses.

Figure 9. Tomato fruit rot caused by late blight.

4. FUSARIUM WILT

4.1. Introduction

Fusarium wilt, the most common tomato wilt disease, is caused by the fungus *Fusarium oxysporum* f.sp. *lycopersici*. *Fusarium* wilt is found worldwide and even resistant tomato varieties may be affected. The fungus is soil borne and makes its way into the plant through the roots. *Fusarium* wilt disease is a soil borne and can persist for many years in the soil even if no host plants are grown. It does not spread

above the ground from plant to plant. Each plant is individually infected when the organism enters the root system. This pathogen invades the vascular system (xylem tissue that moves water and some nutrients) and disrupts water flow through the plant. It clogs and blocks the xylem preventing water from traveling up the stem and out into the branches and leaves. The fungus survives and persists indefinitely in field soil. The disease is most serious in sandy soils and at temperatures between 27°C to 32°C. Soils become infested by planting infected transplants and from movement of infested soil by wind and water erosion or on farm implements.

4.2. Symptoms

Plants are susceptible at all stages of development, but symptoms are most obvious at or soon after flowering. Diseased plants first develop a yellowing of the oldest leaves (those nearing the ground). The bright yellowing which is restricted to one side of the plant or even to leaflets on one side of the petiole is considered as a recognized characteristic of tomato *Fusarium* wilt (Figure 10) [16]. The affected leaves soon wilt and dry up but they remain attached to the plant. The wilting continues successively on younger foliage and eventually results in the death of the plant. The stem remains firm and green on the outside but exhibits a narrow band of brown discoloration in the vascular tissue (Figure 11) [17]. This discoloration can be viewed easily by slicing vertically through the stem near the soil line and looking for a narrow column of browning between the central pith region (middle tissue of the stem) and the outer portion of the stem. The brown streaking in the vascular tissue of infected plants becomes plugged during the attack by the fungus, leading to wilting and yellowing of the leaves. Infected plants often die before maturing.

Figure 10. Tomato *Fusarium* wilt.

Figure 11. Vascular browning caused by *Fusarium* wilt on tomato stem.

5. VERTICILLIUM WILT

5.1. Introduction

Verticillium albo-atrum and *Verticillium dahliae*, the fungi that cause *Verticillium* wilt, can attack more than 200 plant species, including potato, pepper, eggplant, strawberry, black raspberry, watermelon, radish, and many common weeds. The fungi causing this disease overwinter in the soil as mycelium or on plant debris as microsclerotia. It invades the plant through the root system causing harms to the vascular system which results in disrupting water and mineral uptake within the plant. Infection and disease development in *Verticillium* wilt develops best at relatively cool (13-23°C) soil temperatures.

5.2. Symptoms

Wilting is the most characteristic feature of infection by *Verticillium* spp. Symptoms usually appear on the older leaves in mid-August when infected plants wilt during the warmest part of the day, and then recover at night [16]. Leaf edges and areas between the veins turn yellow and then brown. In addition, infected plants often have a characteristic V-shaped lesion at the edge of the leaf occurring in a fan pattern (Figure 12) [17]. Unlike *Fusarium* wilt, symptoms of *Verticillium* wilt do not progress along one side of a leaflet, branch, or plant. *Verticillium* wilt causes uniform yellowing and wilting of the lower leaves. As the disease progresses, younger leaves begin to wilt and die, until only a few healthy leaves remain at the top of the plant. Although diseased plants are not killed, they are stunted and weak and produce small fruit [16]. *Verticillium* wilt can be detected by presence of the internal browning streaking of vascular

system in stems (Figure 13) [18]. The discoloration is most pronounced near the soil line and does not extend quite as far up the stem. These symptoms are similar to those caused by *Fusarium* wilt, but vascular streaking caused by *Fusarium* is generally darker and progresses further up the stem than streaking caused by *Verticillium*.

Wilt caused by this disease may be differentiated from drought-stress based on the portion of the plant that is wilting and on the location of wilted plants. Diseased plants often have only a portion of the plant wilting, such as one or two stems. In addition, diseased plants usually appear in patches within the growing area. Plants suffering from drought, however, are uniformly wilted and occur throughout the growing area.

Figure 12. *Verticillium* wilt foliage symptoms on tomato plant.

Figure 13. Verticillium wilt symptoms of cut stem in tomato plant.

6. ANTHRACNOSE

6.1. Introduction

Anthracnose is a frequent problem in the latter part of the growing season on ripening tomato fruit. The disease results in a fruit rot that reduces the quality and yield of tomatoes. *Anthracnose* is caused by several fungal species in the genus *Colletotrichum*, including *C. coccodes, C. dematium, and C. gloeosporioides* [19]. The fungus can survive in infected plant debris and in the soil. During rainy weather, fungal spores are splashed onto the fruit. Most infection takes place on ripe or overripe fruit. Green fruit also can be infected, although symptoms do not develop until the tomatoes begin to mature. Disease development is favored by frequent rainfall temperatures around 26°C. The fungus survives the winter on diseased tomato vines, in the soil, and in seeds. Weeks before the fruit ripens, *anthracnose* can become established on leaf spots caused by other fungi or by insect feeding injuries. Warm, wet weather causes the disease to spread and symptoms to develop. While insect or other wounds facilitate infection, tomatoes can also become infected in the absence of wounds.

6.2. Symptoms

Although symptoms do not appear until the fruit is ripening, the infection occurs when fruits are small and green. Symptoms of *anthracnose* appear first as small, circular, slightly sunken lesions on the surface of ripening fruits (Figure 14) [20]. The spots quickly enlarge, become bruise like depressions, and develop a water-soaked appearance directly beneath the skin (epidermis) of the fruit. As these spots expand, they develop dark centers or concentric rings of dark specks. The rings consist of numerous small spore-producing bodies of the fungus (microsclerotia and acervuli) (Figure 15) [21]. In moist weather these bodies exude large numbers of spores, giving diseased areas a cream to salmon-pink color [22]. By this stage, decay has penetrated deeply into the tomato flesh. Spotted fruits often may rot completely because of attack by secondary fungi through anthracnose spots. After infection, the fungus "rests" between the cuticle and the epidermis of the fruit [23]. The fungus is activated by exposure of the fruit to low temperatures, fruit maturation or plant stress. As fruit ripens, symptoms begin to appear and susceptibilities increase. Eventually the entire fruit will rot, especially when there are several *anthracnose* spots or decay organisms enter the diseased tissue (Figure 16). Fruit nearest to the ground are most likely to be affected aand the fungus can also infect roots [24].

Despite all this apparent destruction, *Colletotrichum* is considered a weak pathogen and can often be controlled through good cultural practices [25]. The pathogen overwinters on infected plant debris, so it is very important to dispose of rotten fruit and infected plants. Because of the ability of this fungus to persist in the soil, tomatoes and other solanaceous crops, like peppers and eggplants, should be rotated on an every-other-year basis [26].

Figure 14. Circular sunken lesions on ripening tomato fruit caused by *anthracnose.*

Figure 15. Fruiting bodies at the center of the lesion on ripe tomato fruit.

Figure 16. *Anthracnose* tomato fruit rot.

7. BUCKEYE ROT

7.1. Introduction

Buckeye rot caused by the soilborne fungus *Phytophthora* primarily infects fruit lying on or near moist soil. Large amounts of rainfall or frequent irrigation may result in the sudden appearance of buckeye rot. Saturation of the soil stimulates the release of zoospores (motile fungal spores) from sporangia in the soil. Buckeye fruit rot most commonly occurs under prolonged warm, wet conditions [27]. The buckeye rot fungi may be introduced through infected seeds or transplants, or through volunteer plants from the previous crop. Fungal spores are produced when the soil is wet and above 18°C. Spores are spread by surface water and splashing rain. Fruit may become infected when they come into contact with infested soil or when being splashed with mud containing fungal inoculum.

7.2. Symptoms

The initial symptom on the fruit is a grayish green or brown watersoaked spot that usually appears near the blossom end, or at the point of contact between the fruit and soil [28]. The spot further enlarges and develops into a lesion with a characteristic target-like pattern of concentric rings of narrow dark brown and wide light brown bands that resemble the markings on a buckeye (Figure 17) [29]. Fruit symptoms caused by buckeye fruit rot can be confused with symptoms of “late blight,” which is caused by the fungus *Phytophthora infestans* [30]. Buckeye fruit rot lesions are at first firm and smooth surface and lack a sharply defined margin, whereas late blight lesions are typically rough and sunken at the margins. Buckeye fruit rot may produce a white, cottony fungal growth on the lesion under moist conditions (Figure 18) [31]. The buckeye rot fungus can affect both green and ripe fruit. Diseased fruit are usually located nearest the ground in staked tomatoes.

Figure 17. Brown concentric rings cused by buckeye rot on tomato fruit.

Figure 18. Buckeye rot fungus affect both green and ripe tomato fruit.

8. SOUTHERN BLIGHT

8.1. Introduction

Southern blight, caused by the soilborne fungus *Sclerotium rolfsii*, which is nearly impossible to eradicate even though it exists in relatively low levels. The fungus infects the lower stem of the plant near the surface of the soil [32]. It is called Southern blight because it cannot survive for long stretches in frozen soil and therefore only thrives in warm climates. *Sclerotium rolfsii* can attack any parts of a plant that touch the soil, but it most commonly attacks a plant at or just below the soil line. Southern blight is favored by by high humidity and soil moisture and warm to hot temperatures (29-35°C). Disease severity increases when undecomposed organic matter is left on and in the soil. Southern blight is extremely difficult to manage because the fungus has a wide host range (more than 500 plant species in 100 plant families), which limits the use of crop rotation. Sclerotia can survive in the soil for several years, and there are few, if any, commercially available resistant varieties.

8.2. Symptoms

The initial symptom of southern blight is a rapid wilting of the entire plant (Figure 19). A water-soaked lesion on the stem near the soil line rapidly expands, turns brown, and girdles the stem (Figure 20) [33]. The fungus produces white fungal strands (mycelia or hyphae) around infected stem and can be observed on the soil surrounding the plant (Figure 20).

Figure 19. Southern blight on tomato plants.

Figure 20. White mycelia at the base of infected tomato plants, small round sclerotia of *Sclerotium rolfsii.*

Sclerotium rolfsii produces survival structures called sclerotia, which are small (0.04-0.08 inches) that enable the fungus to survive for many years in soils, even through adverse conditions [34]. Sclerotia are first white, later becoming darken to brown spherical structures or orange color. When Sclerotia is fully developed, each sclerotium is about mustard seeds size. The presence of the white mycelium and sclerotia at stem base of afected plants are very useful characteristics for identifying southern blight [35, 36]. The fungus survives in the soil as sclerotia which may build to high numbers when susceptible plants are cropped repeatedly.

After sclerotia germinate, the fungus must first colonize organic debris near the soil surface before the fungus can cause infection. Early symptoms on fruit are circular water-soaked spots followed by soft rot or decay (Figure 21).

Figure 21. Mycelia and sclerotia of *Sclerotium rolfsii* on tomato fruit.

AUTHOR'S CONTRIBUTION

RS: wrote manuscript, searched literature; LB: revised and corrected the paper. The final manuscript has been read and approved by both authors.

TRANSPARENCY DECLARATION

The authors declare that there is no conflict of interests.

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