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Symptomology of major fungal diseases on tomato and its management

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Abstract
Tomato (*Lycopersicon esculentum*) is the second most important vegetable crop next to potato. Tomato is a warm season crop, it requires warm and cool climate. The plant is highly affected by adverse climatic conditions. The warm and cool climatic conditions provide an ideal condition for the development of many foliar, stem and soil-borne plant diseases. Fungal diseases are a major limiting factor for vegetable that cause serious yield reduction leading to severe economic losses. The major fungal diseases in tomato are seedling Damping off, septoria leaf spot, Eary blight, Late blight, Anthracnose, Powdery mildew, southern leaf blight, Fusarium wilt, Verticillium wilt, Buckeye rot. For each disease, main symptoms and their management practices mentioned. This review is based on combined information derived from available literature and expertise knowledge.

Keywords: Powdery mildew, buckeye rot, economic losses, late blight

1. Introduction
Tomato (*Lycopersicon esculentum* Mill.) is one of the most popular and widely grown vegetable in the world. It is one of the important food and cash crop for many low-income farmers in the tropical countries. It is mainly rich in Vitamin C and minerals especially Phosphorus, Potassium and Calcium, and high in palatability it is esteemed in various dishes (Taylor, 1987). For most of the countries it is an important commercial crop bringing in much needed revenue.

As per Linnaean taxonomic classification botanical name of tomato was *Solanum lycopersicum*, on the other hand Miller (1754) proposed the genus name *Lycopersicon* (Latin-Wolf Peach) and afterward proposed the named as *Lycopersicon esculentum* for cultivated tomato and *Lycopersicon pimpinellifolium* for wild tomato. While many other classifications systems have been proposed since then suggested that the Miller classification turn out to be the standard due to its common usage. Tomato called as poor man's orange.

Soil-borne and foliar fungal diseases are a major limiting factor for tomato production. It is critical for effective disease control to recognize the difference between infectious and non-infectious diseases, and the type of microorganism causing an infectious disease be determined. Tomatoes irrigated by sprinkler systems that wet the foliage and fruit are more likely to develop disease problems than those watered by drip or furrow systems. Tomato crop is mostly susceptible to biotic (fungi, bacteria, viruses and nematodes) and abiotic (temperature, sunlight, malnutrition etc.) stresses (Balanchard 1992). These diseases are contagious and can spread from plant to plant in a field, often very rapidly when environmental conditions are favorable. Fungi are the most common cause of infectious plant diseases and can be very destructive. Some of the most common fungal diseases that infect tomatoes include Damping-off, Early blight, Septoria leaf spot, Late blight, Cercospora leaf mold, Fusarium wilt, Grey leaf spot, Powdery mildew, Verticillium wilt, White mold, Alternaria stem canker, Corky root rot, Didymella stem rot, Fusarium crown and root rot, Fusarium foot rot, Southern blight, Buckeye rot.

2. Damping off
Tomato seedlings are prone to attack by several soil borne fungal pathogens that cause serious diseases such as damping-off, wilt and root rot [18]. One of the major causes of seedling loss is damping-off, which is mostly a *Pythium*-induced root rot disease. When the fungi kills newly emerged or emerging seedlings it is known as damping-off, and is a very common problem in fields and greenhouses [8]. Damping-off is an important disease of tomato, which causes significant losses in nurseries on young susceptible transplants [15]. Damping-off is caused by a number of fungi including, *Pythium* species (spp), *Rhizoctonia* spp, *Fusarium* spp and *Phytophthora* spp [20].

Species of the soil organism *Pythium* are more often responsible for damping – off. *Pythium* spp. tends to be very generalistic and unspecific in their host range. They infect a large range of hosts. For this reason, *Pythium* spp. are more devastating in the root rot they cause as *Pythium* spp. are also good saprotrophs, and will survive for a long time on decaying plant matter), [15]. Conditions for the development of this disease are high temperature, high humidity, high soil moisture, poor aeration, high levels of nitrogen fertilizer, and closely sown seed [1] Damping off of tomato occurs in two stages, i.e. the pre-emergence and the post-emergence phase. In the pre-emergence the phase the seedlings are killed just before they reach the soil surface (Figure 1). The young radical and the plumule are killed and there is complete rotting of the seedlings. The post-emergence phase is characterized by the infection of the young, juvenile tissues of the collar at the ground level. The infected tissues become soft and water soaked. The seedlings topple over or collapse.

3. Septoria Leaf Spot

Septoria leaf spot, caused by the fungus *Septoria lycopersici*, is the most common foliar disease of tomatoes. It first appears as small, water-soaked spots that soon become circular spots about 1⁄8 inch in diameter (Figure 3) [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. When conditions are favorable, fungal fruiting bodies appear as tiny black specks in the centers of the spots [32]. Spores are spread to new leaves by splashing rain. Heavily infected leaves turn yellow, wither, and eventually fall off. Lower leaves are infected first, and the disease progresses upward if rainy weather persists. Defoliation can be severe after periods of prolonged warm, wet weather. Infection can osccur at any stage of plant development but appears most frequently after plants have begun to set fruit. The fungus survives the winter in tomato debris. 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 sun scalded. 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.

4. Early Blight

It is also known as *Alternaria* leaf spot or target spot. Early blight, caused by the fungus *Alternaria solani* [4]. It is one of the most common and damaging diseases of tomato. It is primarily a leaf spot and foliage blight, but also may cause a black spotting around the stem end and shoulders of ripe fruits in late autumn. The first symptom of early blight is the appearance of small dark brown spots on the lowest, oldest leaves. These range in size from a pinpoint to 1/2 inch in diameter. When weather conditions are right (25^0 to 30^0 C.) with high humidity, these spots enlarge with a concentric-ring pattern as a result of daily growth and spore production by the organism. This target-board symptom aids in diagnosis of early blight (Figure 3). There is usually a narrow yellow zone around the spots, which fades into the normal green. The spots enlarge, become irregular, and make the leaflets turn yellow and die. Symptoms generally begin to show in midseason after many fruits have set, but become severe later when a heavy fruit load, high soil temperatures, or dry weather stresses the plant. After the lower leaves are damaged or even lost, the symptoms move up the plant and repeat the process. Spots may appear on the main stem to cause partial girdling and further damage to the plant parts above such areas. Excessive defoliation exposes late fruit to sunscald and encourages the "freckles" fruit symptom caused by a related fungus, Alternaria tenuis. Ripe fruits may be invaded by the early blight fungus near the point of attachment to the stem and may exhibit concentric patterns like those on the lower leaves. *Alternaria solani* can live for at least a year in diseased vines [17]. When environmental conditions are right and a tomato plant is nearby, spores arise and infect leaves as described above. The numerous spores in the new leaf spots then splash in rain or irrigation water to other tomato plants under stress, until several disease cycles have been completed and the weather has turned cool [2]. Inadequate fertility and organic matter, minor element deficiency, and lack of soil moisture predispose tomatoes to infection and set the stage for an epidemic where plants have not been protected by fungicides. The fungus can be carried on and under the seed coat.

5. Late Blight

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. Disease symptoms and signs on tomato leaves Lesions begin as indefinite, water-soaked spots that enlarge rapidly into pale green to brownish-black lesions and can cover large areas of the leaf (Figure 4). During wet weather, lesions on the abaxial surface of the leaf may be covered with a gray to white moldy growth. On the undersides of larger lesions, a ring of moldy growth of the pathogen is often visible during humid weather [11]. As the disease progresses the foliage turns yellow and then brown, curls, shrivels, and dies. The late blight symptoms are distinct from and should not be confused with symptoms of powdery mildew disease, the spores of which appear usually on the upper leaf surface of tomato. On tomato petioles and stems Lesions begin as indefinite, water-soaked spots that enlarge rapidly into brown to black lesions that cover large areas of the petioles and stems. During wet weather, lesions may be covered with a gray to white moldy growth of the pathogen [11]. Affected stems and petioles may eventually collapse at the point of infection, leading to death of all distal parts of the plant.

6. Southern Blight

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 [29]. It is called Southern blight because it cannot survive for long stretches in frozen soil and therefore only thrives in warm climates. Southern blight is favored by high humidity and soil moisture and warm to hot temperatures (29-35°C). The initial symptom of southern blight is a rapid wilting of the entire plant. A water-soaked lesion on the stem near the soil line rapidly expands, turns brown, and girdles the stem [22]. The fungus produces white fungal strands (mycelia or hyphae) around

infected stem and can be observed on the soil surrounding the plant (Figure 5).

7. Powdery Mildew

Tomato Powdery mildew associated with *Leveillula taurica*, *Oidium neolycopersici* and *Oidium lycopersici*.

Leveillula taurica: Worldwide Distribution

Oidium neolycopersici: Worldwide Distribution

Oidium lycopersici: Australia, USA (California)

Leveillula taurica: Initial symptoms manifest as light-green to bright-yellow lesions on upper leaf surfaces. Eventually light, powdery fungal sporulation forms on lower leaf surfaces (Figure 6). Under ideal conditions, white, powdery masses of conidia develop on both leaf surfaces. As disease progresses, lesions turn necrotic; if disease is severe, entire leaves will die. Affected plants may defoliate, resulting in reduced yields and small, sunburned fruit.

Oidium neolycopersici and *O. lycopersici*: Disease first appears as small, circular areas of whitish fungal growth with sporulation occurring mainly on upper leaf surfaces. As sporulating lesions enlarge, underlying leaf tissue turns yellow, eventually becoming brown and shriveled. Sporulation that typically occurs on upper leaf surfaces distinguishes Oidium from *Leveillula*, which typically sporulates on lower leaf surfaces. When infection is severe, masses of powdery conidia will cover entire leaf surfaces, as well as petioles and calyces; however, fruit remain uninfected. Oidium neolycopersici has been reported in field-grown tomato but it is primarily an issue for protected culture production

8. Anthracnose

Anthracnose of tomato caused by caused by several fungal species in the genus *Colletotrichum*, including *C. coccodes, C. dematium, and C. gloeosporioides* [26]. *C. coccodes* has been recorded on more than 35 hosts from 13 families, primarily in the leguminosae, Solanaceae and cucurbitaceae. Green and ripe tomatoes can be infected, but symptoms are expressed on ripe fruits. Latency of infection associated with green fruit can be overcome by a period of ow temperature storage symptoms on ripe fruits include circular, depressed lesions with darkened centers (Figure 7). As the fungus colonizes the fruit, a semisoft decay occurs. Anthracnose lesions often merge and result in large rotted areas, which render the fruit unfit for processing.

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 [13]. 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) [7]. In moist weather these bodies exude large numbers of spores, giving diseased areas a cream to salmon pink color [25]

9. Tomato Wilt

Tomato wilt associated with *Fusarium oxysporum Schlecht. f. sp. lycopersici* (Sacc). Fusarium wilt is found worldwide and even resistant tomato varieties may be affected. The pathogen is soil borne and persists for many years in the soil without a host [10, 24]. Most infections originate from the fungus associated with infected tomato debris. Root knot nematode infection makes Fusarium wilt-resistant varieties more susceptible to the fungus because of physiological changes in the root. Disease development is favored by warm temperatures (for example, 27–28 °C), dry weather, and acidic soil (pH 5–5.6). Rapidly growing, highly succulent tomato plants exposed to fertilization with ammonium nitrate are especially susceptible to the disease. The fungus can be disseminated by infected seed or by transplants grown in infested soil. The fungus can be introduced into a field on contaminated equipment, training stakes, packing crates or shoes. Soil particles from infested fields may be blown into disease-free fields First symptoms are yellowing of the foliage, beginning with the lower leaves and working upward. Yellowing often begins on one side of the vine. Infected leaves later show downward curling, followed by browning and drying. The top of the vine wilts during the day and recovers at night, but wilting becomes progressively worse until the entire vine is permanently wilted. Vascular browning can be seen in infected stems and large leaf petioles (Figure 9) [6, 19]. Affected plants and their root systems are stunted. The degree of stunting depends upon time of root infection. Plants infected when they are young will be more severely stunted than plants infected at a later stage.

10. Verticillium Wilt

Verticillium wilt associated with two species of *Verticillium* i.e *V. albo-atrum* and *V. dahlia*, having a host range of nearly 200 plant species. Verticillium wilt is more prevalent in cool weather. *Verticillium* pathogen is a soil-borne and can remain in the soil for many years. Infection occurs when the fungus enters root wounds caused by inter cultural operations, secondary root formation and nematode feeding. In addition, infected plants often have a characteristic V-shaped lesion at the edge of the leaf occurring in a fan pattern [27]. 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 [7]. *Verticillium* wilt can be detected by presence of the internal browning streaking of vascular system in stems (Figure 8) [16]. 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.

Fig 1: Damping off

Fig 2: *Septoria* leaf spot

Fig 3: Early blight

Fig 4: Late blight

Fig 5: Southern blight

Fig 6: Powdery Mildew

Fig 7: Anthracnose

Fig 8: Verticillium wilt

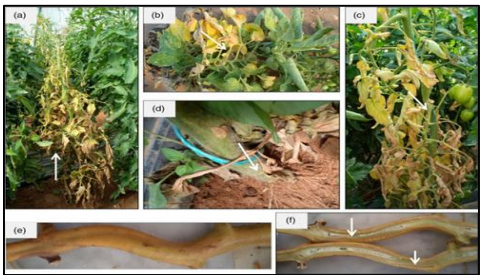

Fig 9: Fusarium wilt

11. Buckeye Fruit and Root Rot

Buckeye rot caused by *Phytophthora nicotianae var. parasitica*, *Phytophthora* capsici and Phytophthora *drechsler*i [28]. These Phytophthora species have a relatively wide host range and can survive in soil and infested plant debris for at least two years. They can be spread by irrigation water and farm equipment. Initial infection is favored by moderate soil moisture levels and temperatures (20°C). Excessive irrigation or rain, in combination with heavy or compacted soils, favors further disease development.

The Phytophthora species that cause buckeye fruit and root rot can infect all parts of tomato plants. They can cause seedling damping-off, root and crown rot, foliar blight and fruit rot. Root rot symptoms include large, brown, sunken, and water-soaked lesions on secondary roots and the tap root that can extend above the soil line onto the stem. As disease progresses, smaller roots collapse and decay. A longitudinal section through the tap root reveals a chocolate-brown discoloration of the vascular system that extends a short distance beyond the lesion. Severely infected plants eventually wilt and die. Infected leaves initially develop water-soaked, irregular-shaped lesions that collapse quickly and dry. Stem lesions can develop at any level on stems but are typically found near the soil line. Stem lesions are dark-green and water-soaked at first, and eventually become dry and brown. As stem lesions expand they can completely girdle stems, causing pith tissue to turn brown and collapse. Fruit symptoms start as grayish-brown, water-soaked lesions that expand rapidly, forming brown concentric rings that resemble a buckeye nut—hence the name [3]. Brown discoloration can extend into fruit centers with young green fruit becoming mummified, while mature fruit quickly rot from invasion by secondary organisms [31].

Table 1: Integrated Management of Major fungal Diseases of Tomato

Integrated Management of Major fungal Diseases of Tomato			
	Diseases	**Cultural Practices**	**Chemical Practices**
Soil borne diseases	1.Damping off	Seed treatment with fungal culture *Trichoderma viride* (4 g/kg of seed) or Thiram (3 g/kg of seed) is the only preventive measure to control the pre-emergence damping off.	Drench with Copper oxychloride 0.2% or Bordeaux mixture 1%. Spray 0.2% Metalaxyl when there is cloudy weather
	2. Fusarium Wilt		Spot drench with Carbendazim (0.1%) Crop rotation with a non-host crop such as cereals [12, 18].
	3. Verticillium wilt	Rotation to nonsusceptible crops, such as small grains and corn helps reduce inoculum	Spot drench with Carbendazim (0.1%) or Benomyl 0.05%.
Foliar Pathogens	1. Powdery midew		Dinocap 48% EC 0.1% or Propiconazol 25% EC @ 0.15% or Tridemorph 80% EC @ 0.15% or Tradimefon 25% WP 0.15% for effective disease control
	2. Late blight	Overhead irrigation should be avoided.	Sparyinmg with mancozeb 0.2% or captafol @ 0.2% or Metalaxyl 0.2% or copper oxychloride @ 0.2% or Tridemorph 80%EC 1.5ml/L
	3. Early blight		Spray the crop with Mancozeb 0.2% for effective disease control [7]
	4. Southern blight	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	Fluxapyroxad+pyracostrobin reduced incidence of southern blight on tomato
	5. Septoria leaf spot		Seed treatment with Thiram or Dithane M-45 (2 g/kg seed) is useful in checking seed borne infection. In the field spraying with Mancozeb 0.2% effectively controls the disease

	6. Anthracnose	Enrich soil with organic mulches. Improve drainage Protect against rain splash	Chlorothalanil 75% WP 0.2% or Benoyml 50%WP 0.1% or Thiopenate methyl 70% WP 0.2%
Fruit rot	Buck eye fruit rot		Metalaxyl+Mancozeb 0.25% or Cymoxinal+ Mancozeb 0.25% spary effectively controls the disease

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