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Late Blight of Tomato and Potato

Elizabeth Bush, Extension Plant Pathologist, School of Plant and Environmental Sciences, Virginia Tech
Steve Rideout, Associate Professor and Vegetable Pathologist Specialist, Eastern Shore Agricultural Research and Extension Center
Christine Waldenmaier, Research Specialist, Eastern Shore Agricultural Research and Extension Center

Introduction

Late blight, caused by *Phytophthora infestans,* is an important and destructive disease on potato and tomato. It has historical significance as the cause of the Irish Potato Famine during the 1840s. This famine resulted in the death of more than 1 million people and the displacement of nearly 2 million more during a short, five-year period.

The Irish Potato Famine is a devastating example of the epidemic potential of late blight. Wet, cool environmental conditions, such as those prevalent during the 1840s in Ireland, favor development of late blight. During wet, cool weather, crop loss due to late blight can be rapid and unstoppable if preventative controls have not been used.

In many areas of Virginia, late blight is not typically an annual problem. However, in major potato-growing regions of Virginia, such as the Eastern Shore, the pathogen may overwinter on potato tubers or on greenhouse tomato plants, making the disease a potential threat each year. When late blight is present in a location (e.g., overwintered) or is introduced (e.g., on transplants or by wind currents carrying inoculum) and environmental conditions are favorable, devastating crop loss can result if preventative control measures have not already been implemented.

A recent problem that makes late blight more challenging to control is the appearance of new strains of *P. infestans* in the United States. In 2009, new strains identified in the mid-Atlantic region were found to be very aggressive on tomato in comparison to the more endemic strains that prefer potato as a host. To make matters worse, these strains had developed pesticide resistance to several groups of systemic fungicides. These fungicides were previously very effective against late blight and commonly used by commercial growers for control of late blight.

The Pathogen: *Phytophthora infestans*

Phytophthora infestans belongs to a group of plant pathogens commonly called “water molds” because of their affinity and special adaptations to water. Until the late 20th century, water molds were classified as fungi. However, as their evolutionary relationships were revealed, they were reclassified within the stramenopiles, a group with many aquatic organisms, such as brown algae.

One important difference between fungi and *Phytophthora* species is that *Phytophthora* species produce motile spores called “zoospores.” Zoospores are chemically attracted to plant tissue and able to swim through water (e.g., in soil, drainage ditches, etc.) toward plant tissue where they form an infective cyst. This characteristic has practical implications because *P. infestans* rapidly produces abundant sporangia (lemon-shaped, zoospore-containing structures) on host tissue during wet, cool weather (figure 1).

The ability to rapidly produce sporangia under favorable environmental conditions is the basis for the epidemic potential of *P. infestans*. Sporangiophores of *P. infestans* are hyaline (clear) and branched with characteristic swollen ends where the lemon-shaped sporangia are produced (figure 2). The sporangia are easily dislodged from the sporangiophores by air currents, mechanical force, and/or splashing water. They are well-adapted for long-distance transport in wind currents to new locations miles away or for splash dispersal from diseased plant tissue onto new tissue or soil where they may release hundreds of infective, swimming zoospores.

There are many strains of *P. infestans*, and they vary in their aggressiveness on potato and tomato. Some

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Figure 1. One lemon-shaped sporangium (zoospore-containing structure) of *Phytophthora infestans* on a sporangiophore and two sporangia that have been dislodged. *Photo by E. Bush*

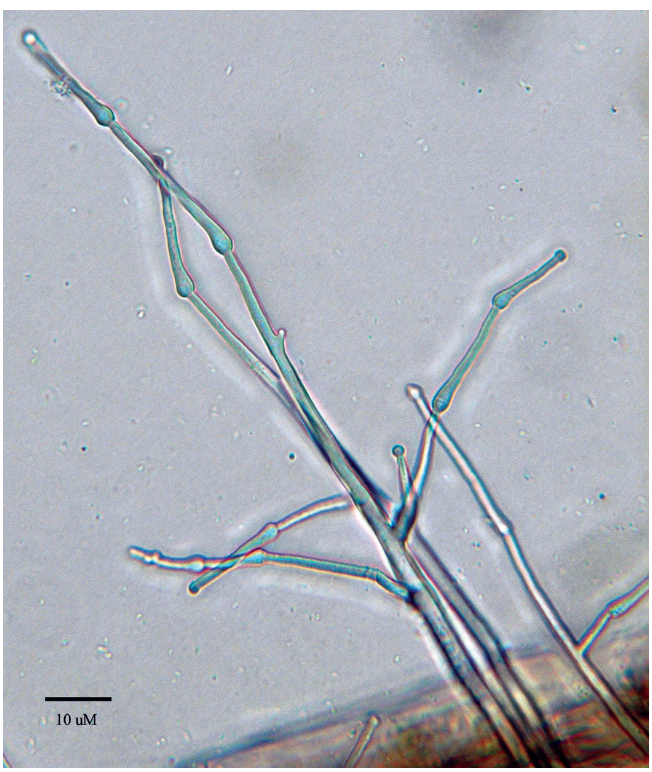

Figure 2. Sporangiophores of *Phytophthora infestans* from which all sporangia have been dislodged on tomato leaf tissue. Note the characteristic swellings on the ends of the sporangiophores. *Photo by E. Bush.*

isolates from potato are not too aggressive on tomato, but some can be aggressive on both tomato and potato, such as the new strains isolated in the United States in 2009.

Symptoms on Tomato

Late blight affects all aboveground parts of the tomato plant. The first symptoms usually appear on leaves as water-soaked, oily, pale or dark-green or brown/black, circular or irregular lesions (figure 3). Typically, younger, more succulent, tissue is affected first (figure 4). During periods of abundant moisture, sporulation of the pathogen can be seen by the naked eye as a white, cottony growth on the underside of affected leaves and/or on fruit lesions (figure 5).

Figure 3. A tomato leaf with the first symptoms of late blight; these typically appear on the leaves as water-soaked, oily, pale or dark green or brown/black, circular or irregular lesions. *Photo by E. Bush.*

Figure 4. Young, succulent leaf tissue is typically first affected by the late blight pathogen. *Photo courtesy of Harold Jerrell.*

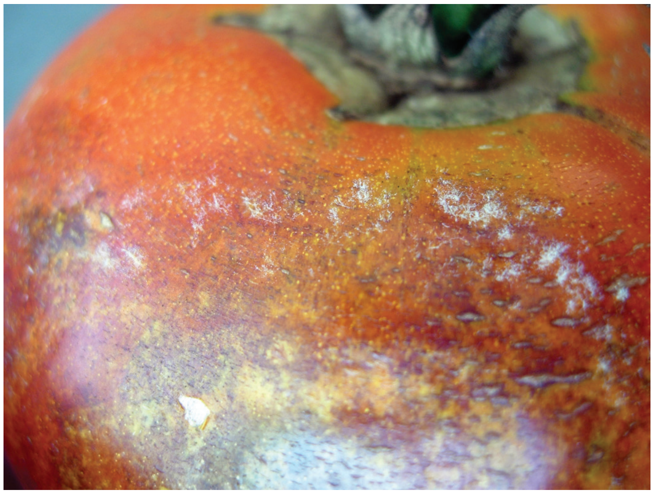

Figure 5. White, cottony sporulation of the late blight pathogen on a tomato. *Photo by E. Bush.*

Figure 7. Oily, brown/copper-colored, sunken lesions of late blight on green tomato. *Photo courtesy of Harold Jerrell.*

When wet and cool conditions are prevalent, the disease usually progresses rapidly through the plant canopy and crop, resulting in brown, shriveled foliage (figure 6). Both green and ripe tomatoes are susceptible to severe injury from late blight. Oily, brown/copper in color, and often-sunken lesions form on both green and ripe fruits, which may remain firm (figure 7). Lesions may spread over the surface of the tomato, and secondary decay organisms generally follow the late blight infection, causing various fruit rots (figure 8).

Often, the stem end of the fruit is affected first (figure 9), because spores tend to land on the top of fruit and small cracks favor infection by the pathogen; however, this is not always the case. Petioles and stems also develop dark, oily lesions (figure 10). The odor from rotting, late-blight-diseased plants and fruits is characteristically foul.

Figure 8. Late blight lesions on tomatoes that have been further colonized by secondary decay organisms, which cause additional fruit rot. *Photo courtesy of Harold Jerrell.*

Figure 6. Under cool, moist conditions, late blight progressed rapidly through this tomato crop, leaving brown and withered foliage. *Photo courtesy of Harold Jerrell.*

Figure 9. Often the stem end of fruit is first affected, because spores tend to land on the top of the fruit and small cracks favor infection by *Phytophthora infestans.* *Photo by E. Bush.*

Figure 10. Dark, oily lesions of *Phytophthora infestans* on the stems of a tomato plant. *Photo by E. Bush.*

Symptoms on Potato

Leaf, petiole, and stem symptoms on potato are similar to those described above for tomato (figure 11). On tubers, copper/brown, irregular lesions form and cause a dry, firm rot (figure 12). Beneath the skin, the flesh is discolored and grainy (figure 13). Tuber rot may extend about 1 inch or less into the tuber when soil conditions are dry, but in wet soil conditions, tuber decay progresses rapidly and tubers may rot completely.

If infected tubers are placed in cool, dry storage, disease progression slows or stops and lesions become dry. However, the disease is not eliminated, and *P. infestans* can resume growth and sporulation when environmental conditions become favorable again. Diseased tubers are prone to invasion by secondary decay organisms that can cause various tuber rots. As with tomato, when wet and cool conditions are prevalent, the disease typically progresses rapidly through the plant canopy and crop (figure 14).[1]

Figure 11. Blighted leaves, petiole, and stem lesions on potato. *Photo by C. Waldenmaier.*

Figure 12. Brownish, irregular lesions on potato with late blight. *Photo courtesy of R. W. Samson, Purdue University, Bugwood.org.*

Figure 13. Discolored, grainy flesh of potato with late blight. *Photo courtesy of Scott Bauer, USDA Agricultural Research Service, Bugwood.org.*

Figure 14. A commercial potato field in the Eastern Shore of Virginia that experienced progressive devastation from the late blight pathogen. *Photo by C.Waldenmaier.*

[1] Additional images of late blight on tomato and potato can be found at the Virginia Tech Eastern Shore Agricultural Research and Extension Center's Facebook page (www.facebook.com/vtesarecpp) and at the Plant Disease Clinic's plant problem image gallery (http://ppwsidlab.contentsrvr.net/plant.vesh).

Disease Cycle

Hosts of *P. infestans* are limited to members of the nightshade family (tomato, potato, pepper, eggplant, petunia, and some weedy members of the family, such as hairy nightshade). *P. infestans* is an obligate pathogen; therefore, it cannot live in the absence of living host tissue. Unlike many pathogens, *P. infestans* cannot overwinter on dead plant tissue, on stakes, or in soil.[2] It is also not seedborne. However, *P. infestans* can survive in infected potato tubers, and volunteer plants growing from infected tubers during the following growing season can serve as a source of inoculum for new outbreaks of late blight. Zoospores of *P. infestans* can also be carried in wind currents for long distances to initiate disease outbreaks in new geographic areas; late blight is commonly spread to new locations by this means.

Other potential sources of *P. infestans* inoculum are late-blight-infected tomato transplants that are shipped to northern locations from southern areas where freezes do not occur and diseased plants that are overwintered in greenhouses. The former situation occurred in 2009 when late-blight-diseased tomato transplants were shipped from transplant growing operations to retail outlets. This man-made movement of late blight inoculum to northern locations so early in the season, along with favorable environmental conditions for late blight development, contributed to a serious outbreak of late blight that was unusual in terms of the widespread extent of the disease in the Northeast, Southeast, and Midwest relatively early in the season.

Production of zoospores and infection by *P. infestans* are rapid when daytime temperatures are between 70 and 80 degrees Fahrenheit, nighttime temperatures are between 50 F and 60 F, and rainfall or abundant moisture is present. Moisture is necessary for sporulation and infection. When temperatures rise above 86 F, *P. infestans*' ability to sporulate and infect new tissue is hampered. Therefore, new late blight infections do not occur during hot weather, and the disease does not spread rapidly.

Infested potato foliage that drops to the soil leads to tuber infection. Zoospores produced on the foliage move through water to tubers where they infect and colonize tubers. Soil temperatures below 65 F are necessary for potato tuber infection to occur.

Preventative Tactics to Avoid Late Blight

Tactics to prevent late blight, including cultural controls and fungicide applications, should be implemented before the disease is present in the garden or field (refer to the bulleted list of tactics in the box below). This is because under favorable environmental conditions (cool and moist) the late blight pathogen spreads extremely rapidly through the crop, producing abundant amounts of inoculum that initiate new infections. A grower who waits until the disease is present in a crop to begin control tactics generally will be fighting a losing battle if environmental conditions are favorable for disease.

Preventative tactics for late blight should be implemented before the disease is present in the garden or field. Both cultural controls and preventative fungicide sprays are necessary to manage late blight. Preventative tactics include:

- Purchase disease-free transplants and seed tubers.
- Bury, dispose of, or properly compost potato culls rather than forming cull piles.
- Remove volunteer potato plants.
- Remove and dispose of late-blight-diseased plants in garden settings.
- Reduce periods of leaf wetness by spacing plants adequately, limiting the size of the plant canopy, avoiding overhead irrigation and morning irrigation, staking plants, and locating plants in areas with good air movement.
- Avoid excessive use of nitrogen fertilizer.
- Consider using cultivars with resistance to late blight.
- Apply pesticides before the disease is in your garden or field when conditions are moist and cool and late blight is a threat in your area (e.g., late blight has been identified in nearby regions).
- Apply pesticides so thorough coverage of plant tissue is achieved.
- **Commercial growers:** Use disease-forecasting-system information to manage late blight.
- **Noncommercial growers:** Use your local Virginia Cooperative Extension (VCE) office to monitor likelihood of late blight in your area.

[2] Currently known populations of *P. infestans* in the U.S. are clonal lineages. This is an indication that *P. infestans* is not sexually reproducing and spread of the pathogen is occurring only through production of sporangia, which occurs asexually. To sexually reproduce, *P. infestans* requires the presence of A1 and A2 mating types in a location. Both A1 and A2 mating types have been found in locations in the U.S.; however, there is currently no indication that sexual reproduction has occurred. This is of practical significance, because sexual reproduction by *P. infestans* results in a thick-walled sexual structure (oospore) capable of survival for long periods of time in soil. In other areas of the world, *P. infestans* does sexually reproduce and may overwinter in the soil.

Cultural Controls

There are a number of cultural controls that can be implemented to minimize infection and spread of late blight. Cultural control tactics and preventative fungicide sprays should be used together in an integrated pest management program for the best chance of controlling this disease.

Purchase Disease-Free Transplants and Potato Seed Tubers

After diseased tomato transplants were shipped throughout the Northeast in 2009, the tomato transplant-growing industry implemented practices to avoid this situation in the future. However, it is still advisable to carefully examine any tomato transplants for symptoms of disease before purchasing. Purchase certified seed tubers from reliable sources and examine them carefully upon arrival and before planting.

Sanitation

It is advisable to bury, dispose of, or properly compost potato culls rather than forming cull piles. Piles of culled tubers may not freeze entirely, and *P. infestans* can overwinter on tissue that is not completely killed. Remove volunteer potato plants as soon as they appear or kill them with herbicide. Removing late-blight-diseased plants to prevent spread to other plants is not likely to be effective, because this disease spreads so rapidly and produces so much airborne inoculum. Nevertheless, removal of late-blight-diseased plants is recommended in garden settings to reduce inoculum available for new infections. Options for disposing of diseased plants include tilling or burying plants, placing plants in plastic bags, and covering plants with a tarp until the tissue is completely killed.

Environmental

Any cultural practice that reduces leaf wetness (e.g., spacing plants adequately, limiting the size of the plant canopy, avoiding overhead irrigation, irrigating in the morning to promote foliar drying, staking plants, planting in locations with good air movement) is recommended. Avoid excessive use of nitrogen fertilizer, which promotes succulent tissue that is more prone to infection, and large foliar canopies that favor leaf wetness and make thorough pesticide coverage unlikely.

Resistance

Tomato and potato cultivars with varying resistance to some races of *P. infestans* have been developed, and breeding for resistance in tomato and potato is ongoing. Cultivars resistant to all races of the pathogen are not currently available, so late-blight-resistant plants are not reliable in all cases. In general, heirloom cultivars of tomato are more susceptible to late blight infections than more recently released cultivars. Growers should keep informed of the current availability of late-blight-resistant cultivars.

Disease Forecasting

Home gardeners are advised to check with their local Virginia Cooperative Extension agent (www.ext.vt.edu/offices/) when environmental conditions favorable to late blight (i.e., cool and moist) are prevalent to determine if preventative fungicide treatments are advisable (e.g., if late blight has been identified in nearby regions).

Commercial producers should use information from disease-forecasting systems, such as BLITECAST or WISDOM, to determine when late blight is a threat in their areas and fungicide treatments are advisable. The use of disease-forecast systems reduces the amount of fungicide sprays needed to effectively manage late blight. The Virginia AG Pest Advisory (www.sripmc.org/Virginia) sends electronic pest alerts and recommendations about fungicide applications to commercial producers, crop consultants, and Extension agents. To sign up for alerts from the Virginia AG Pest Advisory, contact your local Extension agent.

Pesticide Control Recommendations for Home Gardeners

Home gardeners must rely on repeated applications of preventative fungicides to avoid late blight problems. Spread of late blight is so rapid under favorable environmental conditions that fungicides must be applied **before** the disease is observed in order to be effective.

If the weather in your location is predominantly hot (above 86 F) and dry, preventative sprays would not be recommended. If weather conditions are predominantly cool and moist, your local Virginia Cooperative Extension agent (www.ext.vt.edu/offices/) can assist you in determining if preventative pesticide applications may be advisable. This will depend on whether or not late blight has been identified in nearby locations. VCE specialists and agents monitor weather conditions and regional late blight activity to determine if preventative applications of fungicides are recommended in Virginia counties.

If a fungicide application is needed, thorough coverage of plant foliage is essential for effective late blight control, and repeated applications will be necessary (follow product label directions and rates). For information on pesticides labeled for management of late blight on tomato and potato, refer to VCE publication 456-018, the current VCE Pest Management Guide, available online at http://pubs.ext.vt.edu/456/456-018/456-018.html or your local Virginia Cooperative Extension office (www.ext.vt.edu/offices/).

Pesticide Control Recommendations for Commercial Growers

Conventional Production

For up-to-date fungicide recommendations, refer to the current VCE publication 456-420, "Commercial Vegetable Production Recommendations" (http://pubs.ext.vt.edu/456/456-420/456-420.html) or your local Virginia Cooperative Extension office (www.ext.vt.edu/offices/).

Pesticide Resistance Considerations for Conventional Producers

Systemic phenylamide fungicides, such as mefenoxam or metalaxyl, were first available for control of late blight in the late 1970s. Prior to their introduction, late blight control depended on repeated applications of broad-spectrum, preventative fungicides. Phenylamide fungicides were very effective at late blight control, but they were also at very high risk for development of pesticide resistance in the pathogen populations.

Unfortunately, pesticide resistance by *P. infestans* to products containing mefenoxam/metalaxyl occurred rapidly in locations where these fungicides were not tank-mixed with broad-spectrum, preventative pesticides. Growers are strongly advised to strictly follow practices that will avoid development of pesticide-resistant *P. infestans* populations when using products that contain mefenoxam/metalaxyl or any other chemistry at risk of pesticide resistance development (see the following box for suggestions).

Avoiding development of pesticide resistance when using at-risk pesticide products:

- Use at-risk products only as protectants, not as eradicants.
- Apply at-risk products in a mixture with a broad-spectrum protectant product, following label rates.
- Apply foliar applications to control foliar outbreaks.
- Limit sprays of an at-risk product to two to four consecutive applications in a crop annually, with applications no more than 14 days apart. Overuse of these products favors development of pesticide-resistant strains of the pathogen.
- Refer to the product label for further fungicide-resistant, risk management information.

Commercial Organic Potato and Tomato Production

Organic potato and tomato producers must rely on Organic Materials Review Institute-listed products (www.omri.org/) labeled for control of late blight on tomato/potato, such as copper and sulfur products and selected biological fungicides. These products must be applied preventatively, and repeated applications will be necessary when environmental conditions are favorable. Thorough coverage of foliage is essential. Follow product label directions and precautions. There are a number of publications and webinars on organic management of late blight at the eXtension website (www.extension.org/).

Greenhouse Production

Greenhouse growers should be aware that petunia (*Petunia* x *hybrida)* is susceptible to late blight. While late blight on petunia has been reported infrequently, there have been outbreaks of late blight on petunia that have been linked to epidemics of the disease on tomato.

Additionally, the disease on petunia has been reported to have been introduced to greenhouses on petunia transplants and bedding plant producers often grow petunia and tomato in the same greenhouse. It is advisable to separate petunia and tomato crops when possible and carefully monitor any transplants introduced to the greenhouse for symptoms of late blight. Because of the epidemic potential of late blight, there is a serious concern that late blight inoculum produced in the greenhouse may serve as primary inoculum to nearby tomato and potato fields.

Any practice that reduces the period of leaf wetness will deter development of late blight, so growers should ensure adequate air flow and promote low relative humidity in the greenhouse. Growers should also avoid overhead irrigation of petunia and tomato, because this causes long periods of leaf wetness. Growers should scout susceptible crops during cool, wet weather and when late blight has been reported in the area. New susceptible transplants should be monitored closely for symptom development. Once late blight is present in a greenhouse, all affected plant tissue should be removed and destroyed properly.

A limited number of fungicides are labeled for use in the greenhouse. Refer to the product label for application instructions and, because product labels frequently change, refer to a pesticide database, such as Crop Data Management Systems Inc. (www.cdms.net) or the product manufacturer's website for updated labels.

If late blight has been identified in the greenhouse, a fallow period is recommended. During this time, all infested crop debris should be removed and properly disposed of, which will be sufficient for disinfesting, because the late blight pathogen can only be harbored on susceptible, living, host tissue.

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