Late Blight: Recent Occurrences, Management Challenges, and Future Outlook

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Late blight is a potentially very destructive disease that fortunately has been occurring very sporadically in most of the northeastern US most growing seasons. It is the same disease that caused the Irish Potato Famine in the 1840s. The pathogen is well named: 'Phytophthora' in Latin means 'plant destroyer'. Typically potato is the main crop affected because infested tubers have been the main source of initial inoculum of the pathogen (*Phytophthora infestans*). Also, there has been one genotype (strain) occurring during recent years on potato (US-8) that is not as aggressive on tomato. Potato growers have been diligent about implementing a sound management program and recent fungicide registrations mean conventional growers now have several highly effective fungicides to use, thus affected potato crops are less likely to be important sources of the pathogen especially for tomato crops. Other sources of the pathogen that have occurred recently are infected tomato transplants, infected petunia bedding plants (one genotype), and infected crops in frost-free areas that produce spores wind-dispersed to crops in other areas.

The late blight pathogen in Florida has changed recently, which has affected disease occurrence there as well as in other states in the eastern US. Late blight has been occurring most years in Florida since at least 1993. Affected tomatoes in South Florida have been surviving extreme cold periods in December and January, thus late blight has been able to keep on developing into the spring in Florida each year. In contrast with the situation in potato, several genotypes have been detected in Florida with some year-to-year variation in the pathogen population. Since 2005 late blight has continued developing into May in Florida, which is several weeks later than in the past. This suggests a genotype has developed able to tolerate warmer temperatures, and it means this potential source of inoculum persists until crops are being produced north of Florida. Tomato and potato are grown throughout most of the eastern US forming a potential 'green bridge' for the late blight pathogen to progress through eventually reaching the northeast. Since 2005 in the northeast there have been sporadic reports of late blight on tomato appearing from August to October.

2009 was unprecedented especially in the northeastern US because late blight was very widespread, started to develop very early (June), was present on tomato plants for sale at garden centers, and had tremendous impact on growers and gardeners. Genotypes of the pathogen differ in their ability to cause late blight on susceptible host plants. They arise through chance mutation or recombination during sexual reproduction. The genotype on tomato in the northeast in 2009 was fairly aggressive on tomato, but not considered as aggressive as some genotypes that occurred in previous years on tomato, while it was much less aggressive on potato and thus easier to control. US-8 also occurred on potato in some areas in 2009. Additional genotypes were found from FL through PA, likely resulting from pathogen spread northwards through the eastern US. While another year like 2009 is not expected, late blight is expected to continue to occur sporadically on tomato as well as potato, especially where measures are not taken to ensure the pathogen does not survive in the region through the winter.

Late blight occurred less commonly in 2010 than feared. There was a lot of concern after the 2009 epidemic that the pathogen would be surviving throughout the northeast in potato tubers left un-harvested in the ground or kept to use to plant in 2010, and that it would be impossible to educate all gardeners and growers about late blight who did not previously have experience with this disease and thus lacked knowledge about how the pathogen survives. Infested tubers were anticipated to be an especially good way to survive for the main pathogen genotype occurring in 2009 because it is not very aggressive on potato, thus infested tubers would not rot as quickly as when infested by an aggressive 'potato' genotype. There evidently was not a lot of inoculum in the region in 2010, conditions were less favorable with far fewer rain events than in 2009, plus many growers and gardeners were prepared to respond when late blight developed. The source of the pathogen for several occurrences of late blight on tomato in 2010 remains undetermined, which is disconcerting. Potatoes near-by could have been the source, but affected potato plants were not always found. This may be because symptoms caused by a 'tomato' genotype would be harder to find on potato, and the size of many potato crops precludes examining each plant. High tunnels, greenhouses, and gardens were the locations of affected tomatoes found early in the 2010 growing season (May – June). Definitive knowledge of the source of these outbreaks would be helpful for managing late blight in the future.

Currently the late blight pathogen is only known to be able to survive on living host plant tissue (which includes tubers) in the US. It is an obligate pathogen unlike the early blight pathogen that can survive between crops on infested debris. This is because usually only one mating type of the pathogen exists in an area. Mating types are the pathogen equivalent of males and females. When just one mating type is present, the pathogen can only reproduce asexually, which yields ephemeral, wind-dispersed spores (sporangia containing zoospores) that are in the fuzzy fungal growth that is common on affected tissue. When both mating types infect the same plant tissue and grow together, they can reproduce sexually and produce oospores, which are able to survive in soil in the absence of host tissue and during adverse conditions such as cold winter. Both the A1 and A2 mating types have been found in FL, which means the pathogen could reproduce sexually, but oospores have not been found there yet. Most pathogen isolates (individuals) typed recently in other states have been A2, including in 2009. A1 was found in PA and VA in 2009. It is important to understand that both mating types have been present and producing oospores in some areas of Europe (including Scandinavian countries) for at least the past decade, and consequently late blight occurs more regularly and rotation is now needed to manage this disease. This could occur in the US.

Late blight is a challenging disease because it can be difficult to manage, especially when a preventive approach is not taken, and it cannot be 'lived with'. Not managing the disease is rarely an acceptable option because of the huge impact late blight can have on the affected crop as well as crops at other farms that receive spores from an unmanaged outbreak. This is especially problematic for organic growers who choose to produce crops without any approved pesticides. Additionally, if both mating types of the pathogen are present in a crop, when left unmanaged there is greater potential for the two to become together in a plant (this is a chance event) and have the opportunity to produce oospores, which enable the pathogen to survive without living plant tissue as well as evolve new genotypes through sexual reproduction, which is how oospores are produced. Most other diseases can be 'lived with' because the entire crop will not be lost. Late blight can destroy a crop if unmanaged. Affected foliage tissue is quickly killed. Impact is especially great when stems are infected because all tissue above this point will die. Tomato fruit at any stage are susceptible. This disease can be explosive especially under favorable conditions because the pathogen can produce a lot of wind-dispersed spores and it can cycle very quickly, progressing from infection to new lesion (spot) producing spores in about 7 days, but as few as 4 days with a highly virulent genotype. While cool, rainy conditions are especially favorable, late blight can develop in the absence of rain when relative humidity is at least 90%. And genotypes tolerating warmer temperatures have been occurring recently primarily on tomato enabling late blight to develop during the summer.

Many plant diseases affecting foliar tissue can be successfully managed with fungicides by at least weekly inspecting plants for symptoms and/or monitoring conditions, and then starting applications at first detection or when conditions are favorable; but this is not usually possible with late blight, especially in tomato, making management challenging. When symptoms are first seen, too often they are too numerous and widespread in the crop to be able to successfully protect the remaining healthy tissue, even with the most effective, systemic conventional fungicides. Organic fungicides, and few conventional ones, can control the pathogen once established in the plant, thus the pathogen in diseased tissue continues to produce spores. And fungicides cannot 'cure' like human medicines can, nor does the diseased plant have the capacity to 'heal' as animals can, thus the tissue damaged by late blight (or any other disease) will remain so. When late blight begins to develop in a potato crop from infested seed pieces, it can be possible to detect the disease while localized at the source and then destroy the source before spread has occurred. There are programs available that predict the risk of late blight developing based on environmental conditions that have occurred plus forecasts. These do not consider whether the pathogen is present, which of course is essential for disease occurrence, thus anyone using these programs needs to decide the risk of the pathogen being present based on reports from other growers and extension specialists. There is a spreadsheet on the internet for reporting occurrences (see item 7 below). Developing better decision support system to assist growers manage late blight is the goal of research projects underway.

Future outlook depends on growers, plant breeders, researchers, product developers, as well as the pathogen itself. Late blight could continue to occur sporadically as in most recent years if growers (including gardeners) are diligent about management and effective tools are available through the work of plant breeders, researchers, and product developers. The pathogen has proven capable of evolving to overcome fungicides and resistant varieties. Late blight was severe in the US in the 1990s when a genotype appeared that was not controlled by the main fungicide being used by conventional growers. On the other hand, late blight could become a common disease like early blight if both mating types of the pathogen become established together in the north. If this happens it could have a profound impact on production of tomatoes and potatoes, especially for organic growers and gardeners.

Steps for managing late blight in organically produced tomato and potato:

1. Select less susceptible varieties when possible.

   Potato: There are no truly resistant varieties, but some usually are less severely affected than others. Those described as having some tolerance or resistance include Elba, Kennebec, Allegany, Sebago, Rosa, Defender, Jacqueline Lee, and Ozette. Elba is considered the least susceptible. Some organic growers in the northeast reported that late blight in 2009 appeared to be less severe on some other varieties, notably Island Sunshine.

   Tomato: Defiant PhR, Mountain Magic and Plum Regal are the first varieties released with resistance to late blight; later two also have resistance to early blight and Septoria leaf spot. They were developed in the northeast. Marketing of these varieties started in 2011. More are in development. These varieties are all being bred to contain known major genes for resistance. It is important to understand that resistance genes with the greatest suppressive effect tend to have activity for specific genotypes, and this pathogen has potential to evolve new genotypes able to overcome these genes. Therefore, use an integrated management program to minimize selection pressure on the pathogen to adapt and to increase likelihood of effective control. Obtain current information on genotypes occurring. Late blight was observed by growers to be less severe in 2009 on some other varieties, notably cherry types including Matt's Wild Cherry and Sun Gold Cherry. There is more information about tomato varieties and late blight in a downloadable pdf file posted under 'Tomato' at

   http://vegetablemdonline.ppath.cornell.edu/NewsArticles/NewsList.htm

2. Potato: Use certified seed potatoes (which means the producer's crop was inspected and met state requirements that include set tolerances for key diseases). Ask whether late blight occurred where they were produced. Inspect them to ensure none have symptoms of tuber

blight. Infected tubers used as seed or not destroyed from the previous crop are considered the primary source of initial inoculum for late blight in the northeast.

3. Tomato: use transplants produced in an area where late blight is not developing on plants inside or near the greenhouse. Some genotypes of the late blight pathogen can infect petunia and some solanaceous weeds. Inspect transplants carefully before planting to ensure none have symptoms of late blight. The pathogen cannot survive on tomato seed. Best choice is transplants produced in the north in a greenhouse that is not next to a field planted to potatoes.

4. Promptly destroy any volunteer potatoes. These can be an important source of the late blight pathogen. Destroy any cull potatoes before the growing season begins.

5 Control volunteer tomato plants and solanaceous weeds, in particular hairy nightshade and bittersweet nightshade. Other weeds and ornamental plants that are also susceptible to some pathogen genotypes include jimson weeds, golden henbane, climbing nightshade, devil's trumpet, Sodom apple, potato vine, apple of Peru, porcupine tomato, mandrake, tree tobacco, petunia, and calibrachoa. The late blight pathogen cannot survive over winter on these plants, even perennial species, because the pathogen only infects leaves and other tissue killed by cold temperatures; but they do serve as a place where the pathogen, once in an area, can multiple unsuppressed when they are not located in a fungicide-treated crop. But note: if both mating types of the late blight pathogen become established in an area, then survival as oospores in affected weed plant tissue will be possible.

6. Regularly inspect potato, tomato, and tomatillo crops, which are also susceptible, for symptoms of late blight. Local extension office provides diagnostic service. Many images of symptoms are available on the internet to assist with identification. Mine are posted along with additional information at:

   http://www.longislandhort.cornell.edu/vegpath/photos/index.htm

7. Check local extension newsletters each week for information about late blight occurrence. During cloudy conditions spores of the late blight pathogen can survive being dispersed in wind currents potentially long distances because they are protected from the killing effects of UV radiation. Rain is an effective way spores are moved out of wind currents down on to healthy plants, potentially far from the affected plants that were their source. Typical dispersal distance is up to about 20 miles, but much further is possible. A spreadsheet is available for monitoring and reporting occurrences in 2011 on the web:

   https://spreadsheets.google.com/ccc?key=0Ak8NCmWCdGPNdEU1c01VWTZNNGI3c3I2amxjQVo2SFE&hl=en

   2010 reports are at https://spreadsheets.google.com/ccc?key=0Ak8NCmWCdGPNdGlnQWlKTmpEbGNQSHdKT2NTVEl5S2c&hl=en#gid=0 .

   These web sites can also be accessed from the late blight pages in the photo gallery at the simpler web site listed in step 6.

8. Monitor the late blight forecast model at http://uspest.org/risk/tom_pot_map. This provides forecasts of when conditions have been and likely will be favorable for specific locations, but does not consider presence of inoculum, which is usually the limiting factor and thus the deciding factor for outbreaks.

9. When there is a risk of late blight occurring and fungicide applications are going to be used as a component of management, apply approved fungicides on a regular preventive schedule. Limited evaluations conducted to date of individual organic products suggest that copper is

the most effective. Late blight is difficult to control, and can be impossible when fungicides are not applied before disease onset. Thorough spray coverage is critical. See section at end if any fungicide will be used.

10. If symptoms of late blight are found in isolated areas in a planting, affected plant tissue should be immediately destroyed. It is best to do this in the middle of a sunny day after the leaves have dried when there will be fewer spores and those dislodged in the process will likely be exposed to UV radiation, which will kill them. Affected plants could be cut or pulled, then, depending on quantity, put in garbage bags, buried in the ground, or put in a pile and covered with a tarp. Heat that develops from sunlight hitting the tarp will quicken death of plant tissue and the pathogen. For the same reason, garbage bags with affected plants should be left in the sun for a few days before disposal. Another option, especially with large quantities of tissue, is to use a propane flamer. Flamers are a good way to quickly kill foliage, but are not suitable where tomatoes are grown with straw or plastic mulch or trellised. Affected plants (but not potato tubers) can be composted if done correctly to achieve killing temperatures and plants are placed inside the pile, rather than on the top of the pile where they will continue producing spores for a few days until tissue dies.

    Inspect plants daily thereafter for a week in order to find any additional affected plants that develop symptoms. Apply organic fungicides until vine kill with potatoes and final harvest with tomatoes. It is not possible to control late blight by solely relying on removing affected tissue. Even when rain is not occurring, high humidity and dew over night can provide a sufficient moisture period for infection. Especially when conditions are favorable or a highly aggressive genotype is present, it may not be possible to control late blight with the best organic fungicide. Monitor disease development and be prepared to destroy all foliage if late blight isn’t controlled (see step 13 below).

    Aggressive management will minimize the opportunity for both mating types if present in an area to infect the same plant tissue (chance event for spores to land on same plant), grow together, and produce oospores through sexual reproduction.

    Potato: tubers in an affected area could be dug. They should be held in a dark, dry, warm (at least 65F) place for a week, then inspected for symptoms of tuber blight before marketing.

    Potato: do not re-hill potatoes that remain in the field in an effort to protect the tubers because the pathogen can be easily spread on equipment, and the root pruning that will occur may stop plant growth for several days.

11. Promptly inform neighbors growing susceptible crops and also state extension staff when you find late blight so that others can be informed and take action to protect their plants. Due to the potential for spores to move from your plants to others, which could be destroyed if not protected, late blight needs to be treated as a ‘community disease’ for which communication is an important management tool.

12. Work in affected fields last. Between fields, clean and disinfest equipment with a product and rate allowed by your certifier. The NOP national list allows chlorine materials (calcium and sodium hypochlorite, chlorine dioxide), hydrogen peroxide, and peracetic acid.

13. When late blight starts to become severe the crop foliage should be destroyed to eliminate the planting being a source of spores for other tomato or potato plantings on the farm or other farms. Additionally, destroying foliage in a potato crop will protect the tubers from infection. This is an obligate pathogen that needs living host tissue to survive. Propane flamers are a good way to quickly kill foliage, but are not suitable where tomatoes are grown with straw or plastic mulch or trellised. Flail chopping is another option. To initiate plant death with trellised tomatoes, go through the planting and cut all main stems at the base, then come back

through and cut stems further up in the canopy plus trellising line to enable plant removal. Disturb foliage as little as possible to minimize the amount of spores dislodged. It is best to do this work in the middle of a sunny, preferably calm day after any moisture on leaves has dried to minimize the quantity of spores and also their likelihood of survival in the process. Bagging affected tissue or burying is recommended where feasible with small plantings. Piling plants and covering with a tarp is another option.

Applying an organic fungicide to protect remaining potato stems from late blight is not recommended because conditions are much less likely to be favorable for infection once all the foliage is removed.

The late blight pathogen is not able to survive in plant debris unless the pathogen produces oospores, therefore it is not necessary to physically remove affected plant tissue from a field.

13. Potato: harvest tubers after foliage has died but before significant rainfall is predicted. Waiting two weeks to harvest after vine kill is considered to provide an adequate time for spores to die. Rain can wash spores down to tubers. And tubers should not be harvested when wet. Infection is more likely to occur when soil temperatures are cool (below 54F). Avoid bruising and skinning while harvesting. Harvest separately and last any areas that are low or had more severe symptoms of late blight. As described above under 9, tubers from an affected field should not be marketed until checked for blight. Prompt marketing is recommended. If stored, cool down quickly and provide good ventilation in storage. Check stored tubers frequently for symptoms.

14. Potato: destroy any tubers that could be affected. This is the primary way the pathogen currently can survive over winter. Recommended methods include chopping, burial, burning, spreading on fields where they will freeze completely over winter, or feeding to livestock.

15. Tomato: the late blight pathogen cannot survive on stakes, therefore it is not necessary to trash or even disinfect the stakes to manage this disease. Stakes should be disinfected however, especially if bacterial diseases also developed in the planting.

16. Potato: inform customers that tubers from a crop with late blight should be consumed soon as they could have a shortened shelf life and that any tubers not consumed need to be put in the trash rather than composted to avoid providing the pathogen a means to survive over winter. Consider marketing tubers from an affected crop in small allotments to minimize the time consumers will be holding the tubers since they do not have proper storage conditions to slow late blight development.

    Tomato: Fruit from an affected field can develop symptoms after harvest and thus should be inspected just before marketing. Customers should be aware of the potential that fruit could have a shortened shelf life when picked from an affected field. It may be wise to recommend that any fruit that rot be put in the trash rather than on a compost pile since there is a possibility that the pathogen could produce spores before the fruit completely rotted.

High tunnels and greenhouses do not always protect tomatoes from late blight. While often less severe, the disease can still develop because the pathogen does not need leaf wetness for infection and its spores can be dispersed by wind through open vents when the disease is developing on field-grown crops in the region. Relative humidity of at least 90% is favorable. Use cultural practices to minimize humidity and monitor with a sensor.

Additional Information About Copper and Other Fungicides.

OMRI-listed fungicides labeled for late blight include Sonata, Serenade, Sporatec, Regalia, OxiDate, and copper. Companion meets NOP guidelines and is in review with OMRI. Check to make sure product is registered in the state and check with your organic certifying agency to determine what products, including specific copper formulations, are approved. In some states products that are exempt from EPA registration because of their ingredients, such as Sporatec, do not need to be registered in the state (this is the case in NY but not in ME). There is limited data from replicated experiments on efficacy for late blight of products approved for organic production. Copper has provided some control where other products have failed in efficacy trials. Effective control of late blight with copper was achieved by some organic growers in 2009; however, copper is not considered inherently highly effective by pathologists studying late blight management, thus some suspect the main pathogen genotype present in 2009 is not as aggressive as genotypes present in fungicide evaluations. Lack of highly effective organic products, combined with the fact that established spots, being uncontrollable with fungicides, will continue to produce spores, plus the explosive nature of late blight, is why a preventive spray program is recommended including by organic growers in areas where late blight occurs regularly. It is especially important to use a preventive schedule with products such as Regalia and Companion that act by affecting plants' natural defense mechanisms.

Before using any fungicides read the label. Note that the 'signal word' for copper fungicides is 'danger'. The signal word assigned to a pesticide is based on how harmful it might be if swallowed, inhaled, or exposed to skin or eyes of the person handling it. Danger is assigned when the pesticide is highly hazardous by at least one of these routes of entry into a person. The other signal words used for pesticides are 'warning' for moderately hazardous chemicals and 'caution' for slightly hazardous chemicals. In the precautionary statement on pesticide labels is a section on 'hazards to humans', which explains how the product could affect someone exposed to it. This is followed by the 'personal protective equipment' (PPE) that is needed when mixing and applying the pesticide. Hazards for copper fungicides are: 'Corrosive. Causes irreversible eye damage. May cause skin sensitization reactions in certain individuals. Do not get in eyes or on clothing. Harmful if swallowed or absorbed through the skin. Avoid contact with skin.' Also 'avoid breathing dust.' for some formulations. PPE that applicators and other handlers must wear when using copper is: long-sleeved shirt and long pants, chemical-resistant and waterproof gloves, shoes plus socks, and protective eyewear. First aid information is also provided on labels for accidental exposure; know this in advance to avoid delay in treatment. There are also important 'Agricultural Use Requirements' described on labels. This includes the 'restricted-entry interval' (REI), which is 24 hours for copper, what PPE is required for anyone who enters and will contact anything treated before the end of this interval, which for copper is the same as for applicators, and what precautions must be followed after an application, which for copper includes having an eye flush container at the WPS decontamination site for workers entering the field for 7 days after treatment. Note that fruit cannot be harvested during the REI. EPA's Worker Protection Standard for Agricultural Pesticides (WPS) is a regulation that must be complied with on farms where any pesticide is used, including those approved for organic production. Under this regulation, all agricultural workers on the farm must receive pesticide safety training, decontamination supplies, notification of pesticide applications, access in a central location to a log of pesticide applications plus information about these pesticides, any required personal protective equipment, and emergency medical assistance when needed. Restricted-entry intervals must be adhered to. Also, pesticide safety posters must be displayed.

Labels also specify how often the product can be applied. Most copper fungicides are labeled for use every 5 or 7 to 10 days. These labels will change in the near future following re-registration of copper fungicides in the US. Changes will include more explicit use descriptions plus a defined minimum retreatment interval of 5 days and maximum annual rate of 25 lbs metallic copper per acre for potato (these limits are specified in EPA Reregistration Eligibility Decision (RED) for coppers). Applying copper more frequently than every 5 days is not considered necessary, even following rain, because these products are formulated with adjuvants that help keep them on foliage. Labels always should be checked on new product containers for changes such as this before using. It is especially critical where copper is being applied frequently to test soil regularly to ensure this is not resulting in an unacceptable accumulation of copper. Before starting a fungicide program with copper, it is advisable to check with the certifier about limits in addition to those on the label, such as number of applications.

Calibrate sprayers before needed to ensure rate applied will be neither above nor below labeled rate.

When using any pesticide note that it is a violation of Federal law to use the product in a manner inconsistent with its labeling.

Some of this information on management was provided by Dr. Steve Johnson, University of Maine Cooperative Extension

Please Note: The specific directions on fungicide labels must be adhered to -- they supersede these recommendations, if there is a conflict. Confirm state registration and organic approval with certifier. Any reference to commercial products, trade or brand names, is for information only; no endorsement is intended.