BACTERIAL AND FUNGAL DISEASES OF POTATO AND THEIR MANAGEMENT

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MONTANA STATE UNIVERSITY
EXTENSION

EB0225 new January 2017

THE SEED POTATO INDUSTRY IN MONTANA

Seed potatoes are an important crop in Montana and are a crucial quality seed source for potato production across the United States. The cooperation of commercial producers and home gardeners to control diseases of great concern, such as late blight, is essential.

Montana is one of the top five seed-potato producing states. According to the Montana Department of Agriculture, the state's seed potatoes are prized because growing areas are somewhat isolated from airborne spores of diseases such as late blight. To protect this industry, Montana only allows potatoes that originate in Montana to be grown as certified seed, and requires all seed potatoes to be inspected at their shipping point. Businesses can sell garden seed potatoes from outside Montana, but need to be inspected at the point of shipping and have an accompanying health certificate.

BACTERIAL DISEASES

FUNGAL DISEASES

cover photo by Jessica Rupp

BACTERIAL DISEASES OF POTATO AND THEIR MANAGEMENT IN MONTANA

BLACKLEG, AERIAL STEM ROT and SOFT ROT are all caused by bacteria, that via their production of pectolytic enzymes cause a wet, mushy rot of tissues they infect. Pectolytic enzymes dissolve the middle lamella, composed of pectin, which holds plant cells together.

BLACKLEG

General Information

Currently in Montana, blackleg is most commonly caused by *Pectobacterium* spp. In the United Kingdom and Europe another genus of soft rot bacteria, *Dickeya* spp. can cause blackleg and this will be discussed separately.

As infected tubers are the source of this disease and the pathogen is easily spread during seed cutting, blackleg is of great concern to certified seed growers. This disease has been minimized by the tissue culture-based, flush-out certification system used by Montana seed growers.

Symptoms and Spread

Blackleg symptoms include soft rot of seed pieces, black to brown discoloration of the stem extending from the seed piece to above ground portions of the stem, and stunting and wilting of affected stems (Figure 1). In some cases only the interior of the stem may show discoloration. Blackleg infected tubers can show soft rot symptoms in storage, but symptom development is favored by wet soils at planting and temperatures between 50 and 60ºF before emergence and >68°F after emergence. Under unfavorable conditions for disease development, plants may be asymptomatic.

Management

The key to management of Blackleg is disease-free seed. Cleaning seed handling, planting, and cutting equipment is important and this will be discussed in the Soft Rot/Ring Rot disease sections.

AERIAL STEM ROT

General Information

Aerial stem rot, also known as aerial blackleg, aerial soft rot, or bacterial stem rot can be found anywhere potatoes are grown. This disease can be caused by several different bacteria including: *Pectobacterium carotovorum* subsp. *carotovorum* (syn. *Erwinia carotovora* subsp. *carotovora*), *Pectobacterium atrosepticum* and *Dickeya dianthicola* (syn. *Erwinia chrysanthemi*). In Montana, aerial stem rot is typically caused by *Pectobacterium carotovorum* subsp. *carotovorum*, the causal agent of soft rot.

Symptoms and Spread

Aerial stem rot often begins as a water-soaked lesion on the stem that becomes a soft, rotted area. Under dry conditions, stems appear shriveled and dark, while in wet, humid conditions appear soft and slightly water soaked. Internal stem pith is often discolored outside the boundary of lesion edges. When present, external discoloration due to decay ranges from dark green to dark brown, and black. The infection is not tuber borne, and often remains confined to the aboveground portion of the plant. Stem infections occur through wounds or natural openings, such as a leaf scar. Affected stems become wilted and often die. Aerial stem rot is differentiated from blackleg by occurring higher up the stem and spreading downward, whereas blackleg occurs from the ground up. The soft rot bacterium is a common soil inhabitant and is spread by

FIGURE 1. Typical blackleg infection

Photo: Payton Strawser, The Ohio State University

FIGURE 2. Aerial stem rot following hail event

Photo: Barry Jacobsen, Montana State University irrigation, splashing water or insects. This bacterium must infect through wounds with hail injury (Figure 2, page 1) and mechanical damage (equipment, blowing sand) being the most common routes for infection. Where European corn borer is found, their oviposition and feeding sites are another common infection site. Under moist conditions decay is soft and slimy. Factors that lead to prolonged canopy wetness such as rain, dense canopies, excessive nitrogen fertilization, etc. are predisposing factors. Under dry conditions infected tissues rapidly shrivel, and dry up. Warm to hot temperatures are favorable for bacterial replication. Simple molecular laboratory tests can easily differentiate black leg from soft rot bacteria.

Management

Management of the disease can prove difficult. The suggestions for integrated control follow.

1. Plant only clean, certified seed potatoes.
2. Use whole tubers, or allow cut seed pieces to suberize, or cork over, before planting.
3. Use recommended plant spacing.
4. Avoid over irrigation, use less frequent irrigation, with longer durations. Early day irrigation allows for drying to occur later in the day.
5. Avoid over fertilization (especially nitrogen) to prevent excessive vine growth.
6. Avoid stem damage during hilling and use optimal sanitation practices

The use of copper-based fungicides with or without mancozeb is recommended after hail events. Spray programs with famadone + cymoxanil + mancozeb and copper hydroxide + mancozeb have been shown to reduce disease incidence and severity.

SOFT ROT

General Information

This disease can be caused by any one of several pectolytic bacteria including: *Pectobacterium carotovorum* subsp. *carotovorum, Pectobacterium carotovorum* subsp. *odoriferum, Pectobacterium atrosepticum, Dickeya dianthicola* (syn. *Erwinia chrysanthemi*), and certain strains of bacteria in the genus *Pseudomonas, Bacillus* and *Clostridium*. Decay by Clostridium species usually only occurs under anaerobic conditions. Soft rot decay of seed pieces and potatoes in storage is most commonly caused by *Pectobacterium carotovorum* subsp. *carotovorum*, a common soil- and surface water-inhabiting bacteria. Aside from potato it can cause soft rot of nearly any non-woody plant part. This ever-present bacterium invades tubers through wounds or through tissues damaged by frost, anaerobic conditions associated with water-saturated soils or low available oxygen in storage. This bacterium is favored by 70-80ºF temperatures, but can be active at any temperature between 32 and 90ºF with decay and bacteria reproduction being sharply retarded below 50ºF. Soft rot bacteria spread from infected to non-infected tubers via water films in storage.

Symptoms and Spread

Symptoms of soft rot are characterized by soft, mushy decay of tuber tissue. Rotted tissues are typically cream to tan in color. When infected tubers are cut, the margin of the rotted area will turn brown to black with a clear boundary between the rotted and sound tissue. Initial decay is relatively odorless, but as other bacteria begin to grow within the rotted tissue, the odor will become foul. When tubers are harvested from wet soils or washed before storage, lenticel infection is common. Lenticel infections are typically ¼-½ inch in diameter and while still moist, may be raised and slightly darker than the potato skin. Flesh up to ½ inch deep under the infected lenticel is water-soaked and yellow to cream in color. When these infections dry out under dry or cold conditions, they are typically slightly sunken. Un-suberized bruises or wounds are common entry points and seed decay is common when seed pieces have not been properly suberized before planting. Typical symptoms of soft rot are shown in Figure 3.

Management

Management of soft rot requires addressing the ever-present pathogen and its requirement for wounds or damaged tissues for infection. The following are important suggestions.

1. Avoid harvest when temperatures are >65-75ºF, particularly when conditions are wet.
2. Have good skin set before harvest. Generally this requires 10-14 days post vine kill.

FIGURE 3. Typical cross section of tuber affected by soft rot

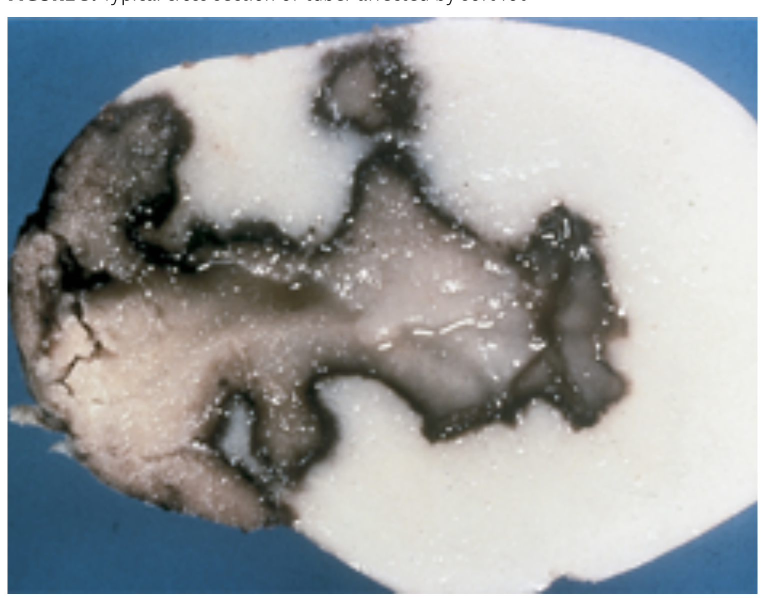

Photo: Courtesy M. L. Powelson. Reprinted from Stevenson, W. R., Loria, R., Franc, G. D., and Weingartner, D. P. 2001. Compendium of Potato Diseases. 2nd ed. American Phytopathological Society, St. Paul, MN.

3. Provide protection for harvested tubers from sunscald, heating or desiccation by tarping loads if exposed for more than several hours.
4. Avoid bruising during harvest and handling.
5. Remove symptomatic or damaged tubers before binning.
6. Place in disinfected storage with clean equipment. This requires the use of soapy water and scrubbing to remove soil and dried potato residues followed by disinfectant, keeping surfaces wet with disinfectant for 10-15 minutes. Table 1 contains information on disinfects for potato storage and handling equipment.
7. Properly suberize potatoes by initial storage at high humidity with good ventilation (no wet surfaces) at 50-55ºF for 10-14 days. Free water will allow spread of soft rot bacteria. This will allow injuries and bruises to cork over. Cork formation in wounds is quite resistant to soft rot bacteria invasion.
8. If frost damage, wait several days to harvest, so symptomatic tubers are obvious. If frost damaged or heavily bruised from dry soil clods, pile separately if possible in as shallow a pile as possible, use dry air and get pile to 38-40ºF as quickly as possible.
9. If frosted or severely bruised, carefully consider using BioSave, Oxidate, SaniDate, StorOx, Jet Oxide or Jet Ag when piling (due to application with water). Thermo-fogging with Jet Ag has also been effective.
10. Avoid washing potatoes into storage. Remove symptomatic potatoes before washing for shipping and dry potatoes as rapidly as possible before shipping.
11. Maintenance of soil calcium levels greater than 1200 ppm will reduce soft rot losses.

The use of chlorine-generating products such as sodium hypochlorite, calcium hypochlorite, chlorine dioxide, and non-chlorine-generating products such as quaternary ammonium, benzalkkonium, chloride, n-alkyl dimethyl benzyl ammonium chloride, N,N,-didecyl-N,N-dimethyl ammonium chloride are excellent disinfectants. Additionally, hydrogen peroxide, iodine, povidone iodine, phenol-glutaaldehyde, formaldehyde, and copper 8 quinolate may be used. Follow all label instructions carefully for use and safety.

RING ROT

General Information

Bacterial Ring Rot is caused by the bacterium *Clavibacter michiganensis* subsp. *sepedonicus* and is perhaps the most serious disease certified seed growers can face. It is a zero tolerance disease. In Montana, this disease has not been detected for many years due to a tissue culture-based nuclear seed program with Polymerase Chain Reaction (PCR) testing of all tissue cultures, a strong flush-out required certification program, strict inspections, strict sanitation on seed farms and more recently, seed lot testing via tuber cores by PCR testing.

Symptoms

Above ground symptoms of ring rot are those that one might expect from a pathogen that reproduces in the vascular system and causes symptoms by plugging the vascular tissue with bacterial cells and slime. Symptoms are most pronounced under dry, and warm to hot (75-90ºF) conditions. Above ground symptoms include wilting starting with lower leaves, rolling of leaf margins, interveinal chlorosis and necrosis (Figure 4). Early in disease development, plants may recover at night. On some cultivars plants will have shortened internodes and exhibit the “dwarf rosette” symptom. If wilted stems are cut, a milky exudate can be seen if the lower stem is squeezed. In general symptoms do not develop until >80 days after planting. Typical above ground symptoms are shown in Figure 4.

Internal tuber symptoms are the most helpful in field diagnosis. Initially the vascular ring starting at the stem end will have a slight discoloration; as time progresses this discoloration will be cream-colored, later turning brown. When the cut tuber is squeezed, a cheesy, cream-colored exudate can be expressed from the vascular

FIGURE 4. Above ground symptoms of ring rot

Photo: J.D. Janse, Plant Protection Service, Bugwood.org system. Later the vascular system will decay and corky tissue and voids will define the area of the old vascular system. External tuber symptoms may include cracking and darkened blotchy areas of the skin. Most tubers developing from infected seed will rot. However, it is important to understand that symptom development is dependent on favorable conditions, bacterial populations in the plant and cultivar. Because of the high financial stakes relative to a ring rot diagnosis, all final diagnoses should be based on PCR confirmation by an authoritative lab. One of the big problems with this disease is that plants/tubers can be infected without showing symptoms. Figure 5 shows typical tuber symptoms.

Clavibacter michiganensis subsp. *sepedonicus* is a vascular pathogen that is primarily seed tuber-borne and spread during seed cutting and handling, although limited spread by mechanical damage via sap transfer in the field is possible, and insect transmission by potato flea beetle, Colorado potato beetle, tarnished plant bug and green peach aphid have been proven. The bacterium does not survive in the soil, but can survive in bacterial slime (biofilms) on potato handling equipment, ventilation pipe, storage shed walls and truck bodies for many months or even years. So long as infected potato residue is un-decayed, it can be a source of inoculum. Once decayed, the bacteria will die, as it cannot compete with other microbes in the soil. The ring rot bacterium can also survive on volunteer potato plants between growing seasons. It can survive for 0-35 days in surface irrigation water at temperatures from 40-68ºF.

Management

Management of this disease is predicated on production of disease-free seed and sanitation. All tissue cultures should be tested by PCR before propagation. It is critical that seed production is limited to 3-5 generations and that each generation be field, storage and shipping inspected. Today, it is also highly recommended that each seed lot be tested in each generation by PCR testing a minimum of 400 individual tube cores. In early generations, a strong case can be made for more extensive testing. Sanitation is a critical step and all potato storage ventilation tubes and handling equipment should be sanitized using of soapy water. Scrub to remove soil and dried potato residues followed by disinfectant, keeping surfaces wet with disinfectant for 10-15 minutes. It is particularly important that seed cutters be thoroughly cleaned and sanitized between lots since a blade cutting an infected tuber can inoculate the next 30-150 seed tubers depending on the population of the ring rot bacterium in the infected tuber. All rollers should be closed-cell since open-cell rollers are nearly impossible to sanitize. All potato hauling truck bodies should be sanitized since bacterial slime from a previous load can contaminate a clean seed lot. Quaternary ammonium disinfectants are considered to be excellent. Never use used burlap bags or crates since these can be contaminated. All used equipment should be thoroughly cleaned and sanitized before coming to a seed farm.

FIGURE 5. Tuber symptoms of ring rot

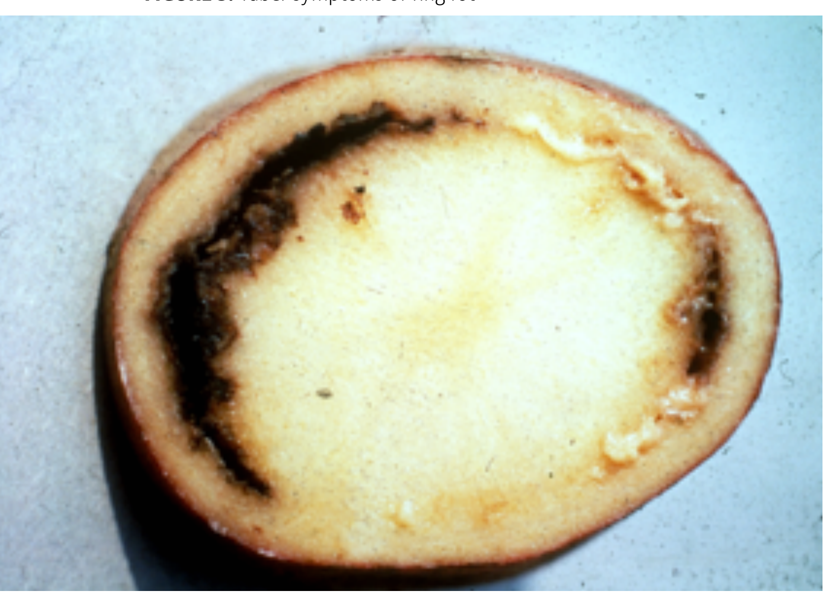

Photo: Central Science Laboratory, Harpenden, British Crown, Bugwood.org

Seed farms should use disinfectant footbaths at storages and at each field. Roguers should use clean Tyvek pants between each field since the pathogen can be moved on sap-contaminated cloth or footwear and cloth is hard to sanitize.

The optimal situation for seed growers is to have a closed system where only tissue culture derived plantlets or minitubers come to the farm and that no tubers from other farms are planted on that farm-tubers only leave the farm. In addition, using only drop or uncut seed in early generations can help since transmission typically occurs during seed cutting.

It is important for Montana seed growers to understand the serious consequences of a positive ring rot find. See Montana State University Rules and Regulations for Certification of Montana Seed Potatoes especially pages 8-11. Implementing the practices above should help prevent and identify Ring Rot in Montana seed potatoes.

BROWN ROT and DICKEYA BLACKLEG are not known to occur in Montana and are subject to quarantine regulations.

BROWN ROT

General Information

Brown rot or bacterial wilt is a serious seed- and soil-borne disease and prior to the identification of Race 3 biovar 2 of *Ralstonia solanacearum,* the pathogen was only of concern in those areas of the world including the southern U.S. where soil did not freeze. Race 3 biovar 2 changed those concerns because the strain of the pathogen can survive in the soil in temperate climates and can be spread via surface water. This strain of *R. solanacearum* is not found in North America but is prevalent in Europe and other locations receiving seed from Europe. If Race 3 biovar 2 were introduced to Montana, it would be devastating to the seed potato industry. Therefore, it is critical that all Federal Plant Quarantine programs be strictly observed.

Symptoms

In many ways, this disease has similar symptomatology with Ring Rot, with the biggest differences being wilt without dead or necrotic leaves early in disease development and the prominent milky ooze when an infected lower stem is placed in water. If this disease is suspected, contact Dr. Nina Zidack, Director of the Montana Certified Potato Seed Program. Figure 6 shows typical symptoms.

DICKEYA BLACKLEG

General Information

This disease is caused by the bacterium *Dickeya solani* and has not been identified in North America. It is now found in the United Kingdom, Israel and Europe. The disease is identical to common blackleg caused by *Pectobacterium atrosepticum*. Evidence from Europe suggests that if this pathogen is introduced, it will rapidly displace common blackleg as it is a more aggressive pathogen. Like *R. solanacearum* Race 3 biovar 2, *Dickeya solani* is a quarantine pathogen and the best way to prevent its entry into Montana is to observe all Federal Plant Quarantine programs and follow Montana seed certification rules. Figure 7 shows typical symptoms. (Note these do not differ significantly from common blackleg.)

FIGURE 6. Gray brown discoloration of vascular tissues and bacterial ooze in potato tuber infected by *Ralstonia solanacearum* race 3 biovar 2.

Photo: Patrice Champoiseau, University of Florida – Institute of Food and Agricultural Services Brown

FIGURE 7. Dickeya blackleg

Photo: Steve Johnson, University of Maine

COMMON SCAB

General Information

Common scab is caused by *Streptomyces scabies*, *S. acidiscabies* and *S. turgidiscabies* and is not to be confused with powdery scab caused by the soil inhabiting fungus *Spongospora subterranean*, which will be discussed under soilborne fungal diseases. In Montana, *S. scabies* is a common soil-inhabiting bacterium. Common scab has also been called russet scab, erumpent scab, and pitted scab. Unlike other bacterial diseases, this pathogen is favored by warm (>70ºF), dry soils.

Symptoms and Spread

Symptoms are shown in Figure 8.

While no potato variety is immune, many varieties will not exhibit overt symptoms if growers maintain greater than 80% field moisture capacity from tuber initiation until 6-8 weeks later, with the most critical time being until tubers are 1-1½ inches in diameter. The high moisture allows developing tubers to be surface colonized by microbes that are inhibitory to *S. scabies*. Growers should avoid spreading un-composted animal manure, as fresh manure can increase soil populations of S. *scabies*.

Maneb or mancozeb seed treatments can eliminate spread by planting infected seed tubers, and PCNB or azoxystrobin in-furrow with fludioxonil seed treatment will provide a dramatic, but not complete reduction of disease on susceptible varieties. When growing susceptible varieties avoid soils with greater than pH 6.0, use mancozeb seed treatments, in-furrow fungicides and green manures. Avoid rotations with red clover. Use of organic materials like ground barley or oats at ~200lbs/Acre applied in-furrow have provided good control in Montana experiments.

FUNGAL DISEASES OF POTATO AND THEIR MANAGEMENT IN MONTANA

ALTERNARIA BROWN SPOT

General Importance

Alternaria brown spot, or brown leaf spot is a common disease found in most potato growing areas. This disease is closely related to early blight, often serving as a point of confusion. Alternaria brown spot, caused by the fungus *Alternaria alternata*, is considered a weak pathogen in Montana. The disease can occur at any growth stage. *A. alternata* has a wide host range and can be found wherever potatoes are grown. The spores and mycelia survive between growing seasons in infested plant debris and soil, infected tubers, and in overwintering debris of susceptible crops and weeds.

Symptoms and Spread

Early symptoms consist of small, dark round necrotic lesions ranging in size from pinpoint to ⅛-inch in diameter. The appearance of the lesion is often confused with that of early blight. As lesions develop they can coalesce. Whole leaves may be affected, drying up, but often remaining attached to the stem. Lesions are unrestricted by large leaf veins, as in early blight. As lesions grow, the surrounding tissue becomes chlorotic. Lesions disintegrate, which often causes the edges of the leaf to curl up (Figure 9). *A. alternata* can survive on plant debris. Infection first occurs when wind blown spores land on leaf tissue. Spores then germinate and penetrate the potato leaf. Overwintering spores are able to withstand extreme weather conditions. In the spring, spores are considered the primary inoculum. Spores landing on susceptible plants germinate and penetrate tissue. Many cycles can occur within a single

FIGURE 8. Symptoms of common scab on potato tubers

Photo: R.W. Samson, Purdue University, Bugwood.org

FIGURE 9. Alternaria brown spot on leaf tissue

Photo: Howard F. Schwartz, Colorado State University, Bugwood.org growing season once primary infections are established. Warm temperatures, extended leaf wetness and high humidity exacerbate the disease. The disease is most severe under overhead irrigation. Spores may infect tubers late in the season. Tuber infection is classified as black pit. Black pit is characterized by small, black pits forming on the tuber surface. The lesions have a defined margin extending up to ⅛ inch into the tuber. Infection can take place at any point in the season.

Management

The disease is controlled through the use of cultural practices and foliar fungicides. Rotation to a non-host crop, such as a small grain is helpful. Irrigation in cool, cloudy conditions should be avoided. Provide adequate fertilization. Fungicides are very efficient for controlling brown leaf spot. Use contact fungicides with broad-spectrum activity. Avoid strobilurin fungicides.

EARLY BLIGHT

General Importance

Early blight on potato is caused by the fungal pathogen *Alternaria solani*. It can be found in all potato growing areas. Symptoms of early blight are easily confused with those of brown leaf spot. Early blight can be differentiated by the larger lesions and presence of concentric rings within the lesion. Dark-colored spores and mycelia of *A. solani* can survive between growing seasons by overwintering on infested debris and susceptible weeds. The spores are capable of overwintering in extreme weather conditions. Spores are disseminated by wind. Spores that land on susceptible leaf tissue germinate and penetrate the leaf tissue.

Symptoms and Spread

Foliar lesions are dark spots. Within the lesion, concentric rings of ridged and depressed tissue form in a target pattern. Lesions begin as circular, but progress to larger, angular regions. The lesions are constrained by veins, unlike brown leaf spot (Figures 10-11). Symptoms often appear on the oldest tissue. Lesions can be from pinpoint to ¼-inch in diameter. When early infection occurs lesions may be larger, often leading to confusion with late blight. Brown or black elongated lesions may also form on petioles and stems. The fungus can overwinter on potato tubers, plant debris, in the soil, or on the soil surface. Primary infections for these sources are considered low. Therefore, early blight lacks dependency on weather conditions unlike late blight. Free moisture is required for spore germination and lesions become visible two to three days after infection. Many cycles of spore production can occur in a single growing season if the disease goes unchecked. Early blight can be spotted on older plant tissues and is often more prevalent on stressed, senescing tissues. The disease can also infect tubers, as germinating spores penetrate the epidermis. Tubers are most often contaminated at harvest by spores in the soil or those originating from desiccated vines.

Management

Crop rotation and destruction of plant debris and weed hosts are used to reduce the sources of inoculum. Rotation to non-hosts, such as small grain crops, is efficient. Avoid over irrigation, allowing leaf tissue to fully dry. Use of tillage practices to bury plant debris also reduces inoculum. Fungicide programs are the most effective means to control the disease. Most protectant fungicides recommended for late blight also have efficacy against early blight. Spray as soon as symptoms appear. These must be applied approximately every 10 days.

FIGURE 10. Early blight symptoms

Photo: Howard F. Schwartz, Colorado State University, Bugwood.org

FIGURE 11. Early blight infection of potato plant

Photo: V. Devappa, College of Horticulture, University of Horticultural Sciences, Bagalkot, Bengaluru, Karnataka, India

LATE BLIGHT

General Importance

Late blight is a disease of great concern. The organism responsible for late blight, *Phytopthora infestans* (Mont.) de Bary, is known as the "plant destroyer." Late blight has the potential to be found anywhere potatoes are grown. Two mating types are present, A1 and A2. When one mating type encounters the other, sexual structures are formed, and fertilizations takes place. In the presence of only one mating type, *P. infestans* reproduces asexually. In humid environments, *P. infestans* produces sporangia and sporangiophores on the surface of the tissue. White, downy growth appears. Direct germination occurs under warm conditions by germ tube. At lower temperatures, sporangia germinate indirectly via zoospores, requiring free water for motility.

Symptoms and Spread

All parts of the potato plant are susceptible to late blight. The disease often appears following periods of very wet weather. On very young leaves, irregular, water-soaked lesions appear. Lesions are dark brown to black (Figure 12), and can appear small at first. A green halo often appears around the lesion. Left untreated, lesions enlarge into circular, necrotic patches. The pathogen can kill all living tissue aboveground in severe infection. Lesions appearing on stems are dark brown to black, with collapsed, water-soaked centers. Lesions on all tissue rapidly expand to full necrosis in just a few days. Tuber infection is characterized by brown, dry, and granular regions that begin superficially, but can then extend deeper into the tuber tissue. Upon peeling back tuber epidermis, reddish brown to dark brown, granular tissue is apparent (Figure 13). Infection appears dry unless there is secondary infection from soft rot. Asexual reproduction of the pathogen requires a living host. Without a sexual cycle, *P. infestans* is an obligate parasite. Therefore, survival between seasons is dependent on tubers. Spores are dispersed aerially from infected material present in storage, cull piles, and soil. Spores germinate within hours in the presence of free moisture. Lesions can result in secondary sporulation in as little as four days. The pathogen prefers moderate temperatures from 60-80ºF with leaf wetness 10 hours a day. Sporangia produced on leaves and stems can be dispersed by wind and rain events. Tubers can become infected at any time from planting through harvest. Sporangia can be washed downward into the soil from the surface.

Management

Late blight is one of the most studied diseases of any crop plant, therefore intensive integrated management tactics exist. No varieties have resistance to all late blight strains, but some have resistance to individual strains. Good field drainage and proper plant spacing for optimal air movement are desirable. Proper sanitation is necessary: destroy cull piles, volunteers, and any infected material. Bury cull piles 2-3 feet deep at a minimum. At planting, seed treatment fungicides exist. Deep hilling can be used to protect tubers from sporangia washing off leaves. Monitor irrigation so that leaves dry during the day. Avoid excessive fertilization to prevent canopy overgrowth. Many excellent weather models exist to aid in the prediction of late blight. Fungicide application is considered an integral part of late blight management. Contact fungicides have proven particularly useful by coating the leaves to prevent development of the pathogen. Use at labeled dose and at regular intervals. Systemic fungicides can be used with varied levels of success following infection. Fungicides selected after infection is detected must be strain dependent. Some strains have resistance to metalaxyl/mefanoxam. In situations where the strain remains unknown, use an alternate fungicide. Infected vines can be destroyed by herbicide or burning.

FIGURE 12. Late blight symptoms on leaves

Photo: Nina Zidack, Montana State Seed Potato Certification Program

FIGURE 13. Late blight symptoms on tuber

Photo: Jessica Rupp, Montana State University

POWDERY MILDEW

General Importance

Powdery mildew can be a disease of economic importance in irrigated and greenhouse settings. This disease is usually only a problem in arid and semi-arid climates, but can appear anywhere. Powdery mildew has an extremely wide host range, but the potato pathotype is host-specific. Powdery mildew of potato is caused by the fungus *Erysiphae cichoracearum* DC.

Symptoms and Spread

The disease begins with brown flecks on the leaves. These flecks can coalesce into larger, water-soaked regions that may appear black. Powdery mildew forms distinctive white, powdery patches on leaves and stems (Figure 14). Allowed to progress, mildew colonies appear on the leaf surfaces that may appear white to gray. Leaves, beginning at the base, yellow then become necrotic. Left unchecked, the plant may die. Fungal conidia are spread via air dispersal. Powdery mildew is an obligate parasite, meaning it requires a living host. The disease develops quickly. High humidity, dense canopies, and low light all favor development of the disease. Large amounts of inoculum can be produced in 3 to 7 days.

Management

Elemental sulfur applied as a dust or spray is sufficient to control the disease if treated before the pathogen is widespread. If the disease is widespread, there are multiple fungicides labeled for use. Be aware of temperature restrictions and spray intervals with the fungicide of choice.

FIGURE 14. Powdery mildew of potao

Photo: Phil Hamm, Oregon

GLOSSARY

germ tube: a short outgrowth, a germinating hyphae

Lamella: a thin layer, membrane

Lenticel: functions as a pore, providing a pathway for the direct exchange of gases between the internal tissues and atmosphere

obligate parasite: a parasitic organism that cannot complete its life-cycle without exploiting a suitable host

Pectolytic enzyme: a protein that is used to break down pectin, a jelly like glue that holds plant cells together

Pith: soft or spongy tissue in plants

Polymerase Chain Reaction: a technique used in molecular biology to amplify a piece of DNA generating millions of copies.

Roguers: a team of individuals who will remove undesirable plants from the field

sporangia: a receptacle in which asexual spores are formed.

sporangiophores: a specialized hypha bearing sporangia

Strobilurin: a group of chemical compounds used in agriculture as fungicides. They are part of the larger group of QoI inhibitors, which act to inhibit the respiratory chain at the level of Complex III.

Suberize: convert into cork tissue

Zoospores: a spore capable of swimming using a flagellum


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