Bacterial Ring Rot on Potatoes

WASHINGTON STATE UNIVERSITY EXTENSION FACT SHEET • FS102E

Introduction

Bacterial ring rot is one of the most serious diseases that affects potato plants and tubers. The bacterial pathogen can be transmitted to potato plants via infected seed tubers; regulatory agencies throughout North America and other areas of the world that manage seed potato certification programs have a "zero tolerance" standard for this disease. Zero tolerance means that detecting a single infected ("positive") tuber or plant during the process of seed certification can lead to rejection of the entire seed lot.

Although the disease cycle of some bacterial pathogens can be relatively straightforward, the disease cycle of ring rot on potato (Figure 1), caused by *Corynebacterium michiganensis* subsp. *sepedonicus,* is not. This bacterium can be efficiently transmitted to plants via infected seed tubers that may either show symptoms or have no obvious symptoms

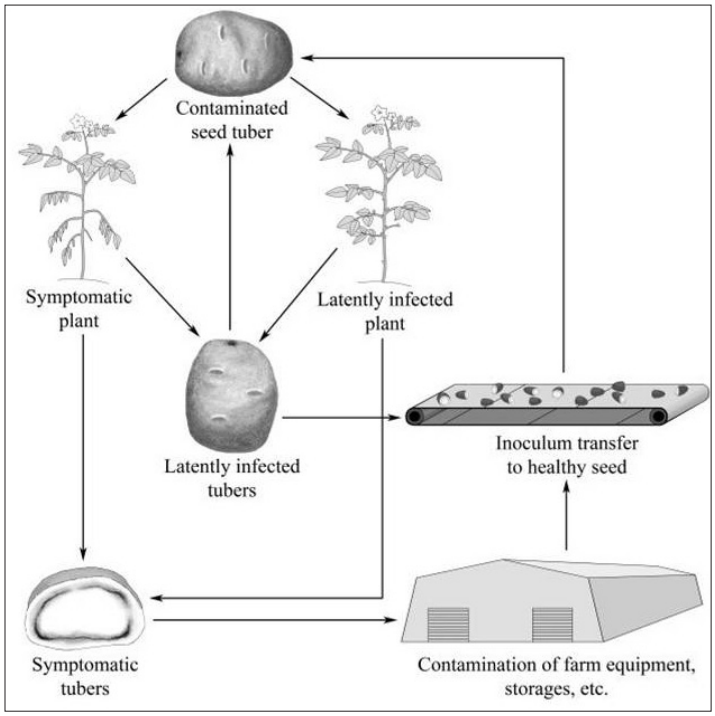

Figure 1. Disease cycle of bacterial ring rot on potato. Diagram courtesy of D.A. Johnson.

of ring rot. Likewise, infected plants may be symptomatic or asymptomatic. Since the pathogen is able to produce copious **extracellular polysaccharides** (mucous-like materials made-up of complex organic molecules which protect the bacteria and aid in their survival), the bacterium can spread easily and adhere indefinitely on all types of surfaces that it contacts.

The pathogen's **latency** (ability to be present in plants without symptom development) and **longevity** (time of survival) complicate both ring rot detection and control. As a result, the successful management of ring rot involves:

(i) exclusive use of certified, ring rot-free seed potatoes, and

(ii) rigorous and thorough sanitation.

These approaches, although outwardly simple, can be very difficult to put into practice. Exclusive use of disease-free seed means that ring rot bacteria must be eradicated from *all* phases of seed potato production, and mandates comprehensive seed inspection and seed certification programs. Rigorous sanitation means that the bacteria must be eliminated from *all* conceivable potato production surfaces from planting through harvest and storage in order to protect otherwise healthy tubers and plants from becoming contaminated.

Ring Rot Pathogen

The causal organism, *Corynebacterium michiganensis* subsp. *sepedonicus,* (formerly known as *C. sepedonicum*, *C. michiganense* pv. *sepedonicum*, and *Clavibacter michiganense* subsp. *sepedonicus*) is a **Gram-positive** (hold stains or resists decolorizing in Gram's method of staining), **non-motile** (cannot move itself) bacterium that grows best, but slowly, at room temperatures (70–75°F), and can survive temperatures below freezing (Davis et al. 2001). *C. michiganensis* subsp. *sepedonicus* produces a slimy ooze of polysaccharides within infected potato tissues which protects the bacterium from environmental stresses and enables its survival for two to five years (perhaps more). Interestingly, this bacterium does not survive well in soil unless associated with undecomposed potato tissue (De Boer 2008). Also, the spread of the pathogen via water is

believed to be negligible in the disease cycle because there are no reports of ring rot bacteria in watercourses or alternative hosts growing along streams or waterfronts (Kaemmerer et al. 2007). *C. michiganensis* subsp. *sepedonicus* primarily affects potato; it grows slowly inside the plant during the early stages of ring rot development, but can increase in number and spread internally. The bacterium is notorious for being able to persist latently (without visible symptoms) at very low concentrations in potato populations as it multiplies during the generation of new seed tubers.

Ring Rot Symptoms and Signs. The first symptoms of ring rot on potato plants of certain cultivars may be shortened **internodes** (the region between two nodes, or joints, on a plant stem) in the terminal shoots; these plants can look "bunchy" and have a dark green color ("green dwarf"; Figures 2 and 3). There can also be **interveinal chlorosis** (yellowing of leaves between their veins), and leaflet margins may roll upward, turn brown and die as they become **necrotic.** Leaves may also appear wilted in a condition known as **green wilt** (Figures 4 and 5) due, in part, to colonization of the plant's **xylem vessels** (water-conducting tissues) by the bacterium. Finally, cut stems may ooze creamy white masses of bacteria.

Figure 2. Early occurring symptoms of bacterial ring rot on potato: shortened internodes and interveinal chlorosis. Photo courtesy of D. A. Johnson.

Figure 3. "Green dwarf" symptom of bacterial ring rot on potato. Photo courtesy of D. A. Johnson.

On potato tubers, ring rot symptoms can show-up at digging, after several months of storage, or *never* if the infection is latent. Yellow (Figure 6) or light brown "cheesy" rings (Figure 7) that give the disease its name may be evident in the **vascular** (water-conducting) tissue, especially at the stem end of the tuber. These rings can become dark colored and also ooze masses of bacteria when squeezed (Figure 7). Often, the tuber will have external cracking and swelling (Figure 8) with additional secondary decay organisms present (Figure 9).

Ring Rot Disease Cycle

To manage bacterial ring rot successfully, it is important to understand the infection process, survival ability, and latency of this bacterial pathogen.

Figure 4. Symptoms of bacterial ring rot on potato: leaf rolling and necrosis. Photo courtesy of D. A. Johnson.

Figure 5. Symptoms of bacterial ring rot on potato: leaf chlorosis and necrosis. Photo courtesy of D. A. Johnson.

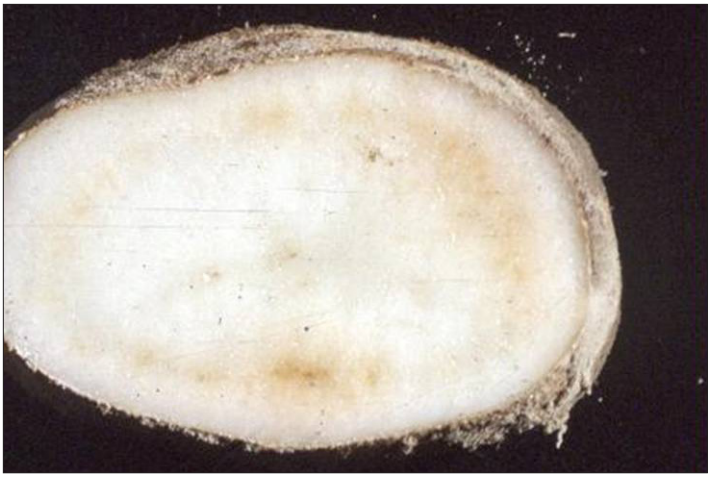

Figure 6. Symptoms of bacterial ring rot on potato tuber showing yellow 'cheesy' discoloration in the vascular tissue. Photo courtesy of D. A. Johnson.

Figure 7. Symptoms of bacterial ring rot on potato tuber: brown discoloration in the vascular tissue and oozing masses of bacteria from parts of the vascular ring. Photo courtesy of D. A. Johnson.

Infection. Wounds are necessary for ring rot bacteria to penetrate and infect seed potatoes. It takes fewer than 300 bacteria to infect a seed piece (Nelson 1982) and a single droplet of ooze can contain millions of bacterial cells. Thus, potato seed cutting operations are the major avenue by which this pathogen spreads. Once cutting knives and belts become contaminated, they are sources of the bacteria for the subsequent seed tubers being cut. Similarly, the bacteria can be spread during planting operations, particularly if a picker-type potato planter is used. During the growing season, chewing insects such as Colorado potato beetle, green peach aphid, and potato flea beetle (Stevenson et al. 2001) may transmit the bacteria from one potato plant to another. Infected volunteer potato plants

Figure 8. Symptoms of bacterial ring rot on potato tuber: external cracking and swelling. Photo courtesy of D. A. Johnson.

Figure 9. Symptoms of bacterial ring rot on potato tuber: the presence of secondary decay organisms in the vascular tissue. Photo courtesy of D. A. Johnson.

can serve as an important source of **inoculum** (pathogen) (De Boer 2008).

Survival. Ring rot bacteria overwinter mainly in infected seed potato tubers. As mentioned above, the bacteria are capable of surviving two to five years in the dried polysaccharide "slime" that arises from infected potato tissue. Therefore, no surfaces—burlap sacks, boxes, crates, bins, truck beds, cutting, harvesting and grading equipment, containers, storage walls, floors, etc.—are exempt from becoming contaminated and serving as sources of continued infection, even at temperatures below freezing.

The bacteria do not survive well in soil in the absence of undecomposed potato debris, but can survive season-to-season in volunteer plants, which makes volunteer potatoes particularly troublesome. Cool and dry conditions promote long term persistence, while repeated wetting and drying cycles decrease the ability of ring rot bacteria to survive in dried slime. Thus, potato storage facilities, equipment, and other surfaces that are under cover or protected from extreme outdoor weather, especially, must be cleaned and sanitized thoroughly in order to eliminate the bacteria.

Latency. Whenever tubers, plants, or both are affected with the ring rot pathogen but do not show symptoms, the infections are regarded as being latent. Latency is a situation where the bacteria exist in the tuber, but the number of bacteria present is too low to result in symptom development. However, the number of bacteria may increase to concentrations that will cause severe damage in subsequent potato generations if the tubers are increased for seed.

Latency can also be the result of environmental conditions that are unfavorable for symptom expression. Furthermore, latency may be a matter of the timing of ring rot symptom expression. It is common for symptoms to develop so late in the growing season that they are overlooked or are masked by natural plant **senescence** (maturity and death).

Conditions that favor the production of desirable seed tubers may also favor latent infections. Those conditions include a short, cool growing season and moderately low levels of supplemental nitrogen fertilizer. As a result, extra care must be used to exclude the infectious bacterium from seed production farms. Finally, there can be cultivar effects such as early-maturing potato cultivars expressing symptoms earlier in the growing season than late-maturing potato cultivars do. Thus, consideration needs to be given to the way symptoms are expressed on different cultivars during field inspections.

Ring Rot Management

Deliberate efforts must be made to minimize the likelihood of ring rot introductions, and also to *immediately* and *aggressively* manage ring rot, if found. Whenever ring rot is detected in a seed lot, the seed lot should not be planted. Further, if ring rot is detected on a farm, extensive sanitation procedures must be employed to remove all potential sources of inoculum and to protect non-infected tubers and plants from becoming contaminated with the bacterium.

Sanitation for seed receiving. Purchase only healthy seed potatoes, certified to be free of ring rot. To minimize the risk of introducing ring rot onto a farm, most states have zero tolerance for ring rot. Some states such as Idaho recommend shipping point inspections for each truckload of seed potatoes received as well as laboratory testing of any seed lots that might be at risk for the disease (Nolte 2005).

Sanitation for seed handling. All trash left from previous seasons, including potato tubers and vines, soil, old bags, broken boxes, etc. should be removed from seed storage areas, and properly discarded or burned. Once trash is removed, bins, walls, and floors in storage facilities, as well as hauling equipment including truck beds, should be thoroughly scrubbed with a high pressure washer using hot, soapy water, and then rinsed well. After washing, a disinfectant should be applied according to label directions.

It is *essential* to wash all surfaces well before applying disinfectant because most disinfectants are not effective on dirty surfaces. Also, to kill bacteria, a disinfectant needs to remain in contact with the treated surface for a minimum of 10 minutes. A foaming agent can be added to some disinfectants to help retain the chemical for the required time if the surface is vertical (walls, doors, etc.). It is important to remember that porous surfaces retain larger populations of bacteria than smooth surfaces do and thus require extra attention in the cleaning and the disinfecting process.

Sanitation for seed cutting. All surfaces that seed potatoes contact must be sanitized. These include all tool, implement, container, and equipment surfaces such as knives, cutters, belts, graders, truck beds, loaders, potato planters, etc. As a rule, clean and disinfect seed cutting equipment at least three times per day, even if processing a single seed lot. Always clean and disinfect before processing different seed lots. It has been reported that open-cell sponge-type rollers can absorb water (and thus, bacteria) so these are best avoided; water-impermeable (closed-cell) rollers should be used instead.

Workers should be provided with personal washing facilities and appropriate disinfectants to help prevent the introduction of the bacterium into cutting areas. Seed lots from multiple sources should be stored/staged with a distinct separation between seed lots, both prior to and after cutting.

Sanitation during planting. Seed lots known to be contaminated with ring rot bacteria should NEVER be planted. Even seed lots suspected to have only been "exposed" to the bacteria may be at risk, so use them with extreme caution, or not at all. Do not plant potatoes in a field with volunteer potatoes and a history of the disease, and do not plant in a field where ring rot was present in the previous year. Avoid picker-type planters and make sure all planting equipment has been thoroughly cleaned. Use of whole seed tubers rather than cut potato seed pieces can eliminate opportunities for tuber-to-tuber spread. Finally, seed from multiple sources should be planted separately, not comingled or blended, with good sanitation of equipment taking place between plantings.

Sanitation for the current growing season. Be vigilant for symptoms and signs of ring rot during the growing season by scouting potato fields and volunteer potato plants on a regular basis. The initial diagnosis of ring rot is usually based on characteristic symptoms seen on potato foliage and/or tubers. However, it is important to be familiar with the various manifestations of the disease (refer back to Figures 2 through 9). Symptoms on foliage can vary by potato cultivar, bacterial populations in plants, and environmental conditions.

Laboratory tests (see "Pathogen Identification," below) should always be used to confirm a ring rot diagnosis. If ring rot is confirmed during the growing season, then delay the harvest so that the infected tubers can break down in the field rather than in storage. In addition, by harvesting an infected field last, you reduce the potential for contaminating your harvesting and storage equipment and for inoculating healthy tubers.

Sanitation for seed potato farms. When ring rot occurs on a seed potato farm, the situation is especially difficult because, in addition to the immense costs of

clean-up and management, there can be loss of reputation (Nolte 2005). An immediate and thorough clean-up must be undertaken to reduce the risk to next season's crop. Follow the practices listed above in "Ring Rot Management." In addition, remove all infected tubers from the seed farm, and dispose of them.

Disposal of infected tubers can be a difficult proposition, depending on the circumstance. Options include taking tubers to a commercial landfill, burning them in some instances, or spreading them on an isolated, non-potato production field where there will be several cycles of freezing and thawing. If the latter, future volunteers must be monitored and removed. Tubers can also be disposed of by burying and covering with at least two feet of soil in an area not intended for potato production for at least one year.

Following disposal, *all* soil and crop debris should be scraped from the surfaces of *all* potato handling implements, equipment, truck beds, and storages. Then, all of these production surfaces should be cleaned and sanitized.

A seed potato crop should NOT be planted for at least two seasons in fields where ring rot has occurred and *strict* control of volunteer potato plants and chewing insects must be maintained to minimize the chance of the bacterium spreading to other potato plantings.

Sanitizing. For general information on cleaning and disinfecting potato equipment and storage facilities, see University of Idaho Extension Fact Sheet CIS 1180 (http://www.cals.uidaho.edu/edComm/pdf/CIS/CIS1180.pdf).

Table 1, below, lists disinfectants that are available in the U.S. for the purpose of sanitizing both potato-handling equipment and potato storage facilities.

Sanitizing agents. Always make sure that the disinfectants you use are registered for commercial use in Washington. WSU's PICOL (Pesticide Information Center Online) website at http://cru66.cahe.wsu.edu/LabelTolerance.html lists current information on which formulations are acceptable for the areas being cleaned. Always follow label directions and worker safety recommendations.

Remember:

- Soil, clay, and organic material can render disinfectants less effective.
- Most disinfectants require that the treated surface remains wet for up to 10 minutes for full activity.
- Addition of wetting agents and foams may aid in desired coverage and penetration.
- Solutions need to be changed frequently to avoid neutralization.

Table 1. Some disinfectants used for sanitizing potato-handling equipment and storage facilities (from Secor, G.A. and S.B. Johnson. 2008. "Seed tuber health before and during planting." Pages 45–53 in: Potato Health Management, Second Ed. D.A. Johnson, ed. American Phytopathological Society, St. Paul, MN). Note: check WSU's PICOL (Pesticide Information Center Online) website at http://cru66.cahe.wsu.edu/LabelTolerance.html for information on which formulations are acceptable in Washington State for the areas being cleaned. For all products, always follow the label directions.

Disinfectant	Inactivation by organic material	Safety	Corrosiveness to metal	Shelf life	Comments
Quaternary ammonium compounds	Some	Caution	Slight	1 to 2 years	Numerous brands; widely used; can be used on stainless steel surfaces.
Hypochlorite 5.25% bleach	Yes	Irritant; caustic to skin and clothing	Yes	5.25% bleach is stable for 6 months at room temperature.	Quick-acting; inexpensive. Use 1:50 mix with water. More effective at pH 7.0 than at normal pH 11.0. For maximum efficacy, mix 1 part 5.25% bleach, 200 parts water, and 0.6 part white vinegar, giving a final concentration of 256 ppm.
Iodine compounds	Some	Relatively safe; caution	Yes	1 to 2 years	Loses activity when yellow-brown color disappears; tamed iodine (iodophor) works best.
Phenolic compounds	Some	Oral poison; caution	No	1 to 2 years	Has residual activity; usually fragrant; the word *phenol* is used on the label.
Chlorine dioxide	Some; not as much as bleach	Prepare with adequate ventilation; fumes caustic; safe at dilution prepared for use.	Yes, especially soft metals such as aluminum and brass.	Activated product is stable for 2 weeks but light-sensitive; concentrate is stable for 1 to 2 years.	Widely used general biocide with broad-spectrum activity against fungi, bacteria, viruses, and algae. Does not produce trihalomethane; breaks down to salt and water.

Fumigation of equipment or a potato storage unit is one alternative for clean-up, but if fumigation is used, a professional applicator with fumigation experience should be chosen to help ensure safety. Note, the number of products registered for this purpose is limited.

Some non-chemical alternatives are available to help contain ring rot bacteria and prevent cross-contamination. Effective methods of containment may include:

- painting wooden surfaces to cover and seal-in the ring rot bacteria;
- covering earthen walls with plastic sheeting to prevent direct contact with stored potatoes;
- removing the top few inches of soil on earthen floors or adding a few inches of new soil, again to protect against or seal-in pathogens; and
- steam cleaning.

Steam cleaning, that is, the use of live steam (not condensed water vapor, which is cooler) can be used as a sanitizing agent but the temperature of the steam contacting the surface must exceed 150°F. The exposure time should be five seconds for fresh bacterial material and 20 seconds for dried bacterial "slime." Steam cleaning may be more practical on individual equipment items, as opposed to steam cleaning an entire potato storage facility.

Seed certification. For a comprehensive review of general approaches used in seed potato certification programs, see Whitworth and Davidson (2008). Not all seed potato certification agencies of different states, provinces, or countries have the same inspection requirements for ring rot. In Washington, all seed potatoes planted for commercial potato production or for seed potato production are required to be certified per Chapter 16-482, Washington Administrative Code (http://apps.leg.wa.gov/WAC/default.aspx?cite=16-482). Further, Chapter 16-324 of the Washington Administrative Code governs the rules for the certification of seed potatoes (http://apps.leg.wa.gov/wac/default.aspx?cite=16-324). A hard copy of the rules can be obtained upon request from Washington State Department of Agriculture – Plant Protection Division, Plant Services Program, PO Box 42560, Olympia WA 98504-2560, or by email from PlantServices@agr.wa.gov.

The Washington State Department of Agriculture oversees seed potato certification through visual inspections of seed potato fields. Potato seed certified in Washington has a zero tolerance for ring rot presence, but the tolerance is not intended to mean that the seed lot that is inspected is free from the disease. The standard simply means that ring rot was not identified during any visual inspection.

For the latest policy changes and requirements regarding ring rot of potatoes in Washington State, please visit the Washington State Department of Agriculture—Plant Protection Division Web site: http://agr.wa.gov/PlantsInsects/PlantServicesProgram/.

Pathogen identification. Proper identification of the ring rot pathogen is a critical step in the management of ring rot of potatoes. Any tubers that are suspect should be tested by the state's certification agency or a reliable diagnostic laboratory. In general, the latent nature of this disease (no obvious symptoms) can make ring rot difficult to detect. Sensitive laboratory methods such as ELISA (enzyme-linked immunosorbent assay), IFAS (indirect fluorescent antibody staining), and various molecular-based procedures are generally used to identify the presence of the bacteria.

When tubers are routinely screened during the seed certification process, generally, 400 tubers are randomly collected and cores of tissue from the stem attachment point are combined, and then tested via IFAS or ELISA (Nolte 2005). Both types of tests are effective for the detection of the ring rot pathogen; however, IFAS is a more sensitive test (Nolte 2005). Molecular methods are available and can be more sensitive, but require the laboratory have a positive control isolate to use for reference. In all cases, care should be taken to follow chain of custody (that is, careful documentation) to properly validate the testing process.

For a listing of diagnostic laboratories that test plants for various plant diseases, see WSU's Pacific Northwest Vegetable Extension Group website (http://mtvernon.wsu.edu/path_team/diagnosticLabs.htm).

Since intensive testing methods and strict due diligence on the part of the potato industry have significantly reduced the occurrence of the ring rot pathogen, it is everyone's responsibility to maintain this due diligence and continue to work to keep this serious pathogen out of Washington potato production.

References

Davis, M.J. and A.K. Vidaver. 2001. Coryneform Plant Pathogens. In *Laboratory Guide for Identification of Plant Pathogenic Bacteria*. Eds. N.W. Schaad, J.B. Jones, and W. Chun. St. Paul, MN: APS Press.

De Boer, S. H. 2008. Managing Soft Rot and Ring Rot. In *Potato Health Management*. 2nd ed. Ed. D.A. Johnson. St. Paul, MN: APS Press.

De Boer, S.H., J.D. Janse, D.E. Stead, J. Van Vaerenbergh, and A.R. McKenzie. 1992. Detection of *Clavibacter michiganensis* subsp. *sepedonicus* in Potato Stems and Tubers Grown from Seed Pieces with Various Levels of Inoculum. *Potato Res.* 35: 207–216.

Kaemmerer, D., L. Seigner, G. Poschenrieder, M. Zellner, and M. Munzert. 2007. Epidemiology of Bacterial Ring Rot of Potato in Plant and Soil – Consequences for Disease Management. *J. Plant Diseases and Protection,* 114 (4), 159–166. ISSN 1861–3829.

Nelson, G. A. 1982. *Corynebacterium sepedonicum* in Potato: Effect of Inoculum Concentration on Ring Rot Symptoms and Latent Infection. *Can. J. Plant Pathol.* 4:129–133.

Nolte, P. 2005. Recognizing and Managing Bacterial Ring Rot. Proceedings of the Idaho Potato Conference. http://www.cals.uidaho.edu/potatoes/Research&Extension/Topic/Diseases/Recognizing&ManagingBacterialRingRot-05.pdf.

Olsen, N. and P. Nolte. 2011 Cleaning and Disinfecting Potato Equipment and Storage Facilities. University of Idaho Extension CIS 1180. Moscow, ID: University of Idaho Extension. http://www.cals.uidaho.edu/edComm/pdf/CIS/CIS1180.pdf.

Secor, G.A. and S.B. Johnson. 2008. Seed Tuber Health Before and During Planting. In *Potato Health Management*. 2nd ed. Ed. D.A. Johnson. St. Paul, MN: APS Press.

Stevenson, W.R., R. Loria, G.D. Franc, and D.P. Weingartner, eds. 2001. *Compendium of Potato Diseases*. 2nd ed. St. Paul, MN: APS Press.

Whitworth, J.L. and R.D. Davidson. 2008. Quality Seed: Seed Improvement, Cultivar and Seed Lot Selection, and Certification. In *Potato Health Management*. 2nd ed. Ed. D.A. Johnson. St. Paul, MN: APS Press.

By **Debra Ann Inglis**, WSU Mount Vernon Northwestern Washington Research and Extension Center; **Dennis Johnson**, WSU Department of Plant Pathology; **Brenda Schroeder**, WSU Department of Plant Pathology; and **Chris Benedict**, WSU Whatcom County Extension.

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