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Managing Bacterial Ring Rot of Potato

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Introduction

BACTERIAL RING ROT is a serious disease of potato caused by the bacterium *Clavibacter sepedonicus*. Although the disease occurs sporadically in North America, it is one of the most destructive, high-risk diseases of potato that has been reported in over thirty countries. The pathogen can easily be spread, especially when seed is cut or if pick-type seed planters are used. Direct yield losses in the field may be low, but losses due to decaying potatoes in storage can be substantial. For a seed grower, the disease leads to considerable negative economic impact due to the loss of eligibility for certification. All growers face additional costs related to sanitizing contaminated facilities and equipment.

Some potato pathogens can survive in the soil, but the bacterial ring rot pathogen does not persist well in soil outside potato tissue. It is considered a tuber-borne disease since infected tubers are a primary source of inoculum. However, once introduced into production areas, the pathogen can survive as a **dried biofilm** (bacteria attached to surfaces and protected by a matrix of proteins and polysaccharides) for years on any surface it has contacted. Rehydrating the biofilm allows the pathogen to become active. The ability of the pathogen to survive for many years as a biofilm and its ability to cause symptomless (latent) infections make management of this disease particularly challenging. Thus, aggressive prevention and sanitation measures are the most important approaches to manage bacterial ring rot.

The Pathogen

Clavibacter sepedonicus (former names include *C. michiganensis* subsp. *sepedonicus* and *Corynebacterium sepedonicum*) is a rod-shaped bacterium that is unusual among plant pathogenic bacteria because it is Gram-positive, while most other plant pathogenic bacteria are Gram-negative. Gram-positive bacteria have a multilayered

Figure 1. Bacterial ring rot symptom of the vascular ring of tubers. The disease gets its name from this symptom. Other diseases can cause similar symptoms, so a laboratory test to confirm is essential.

Figure 2. Early symptoms of bacterial ring rot in tubers. The discoloration of the vascular tissue near the stem end can resemble other diseases and disorders.

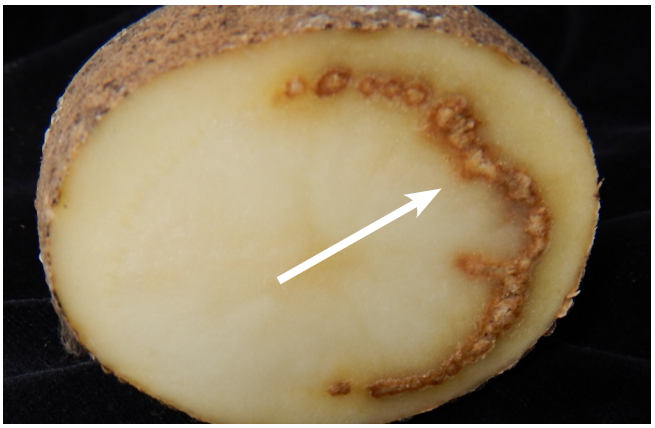

Figure 3. A cream-colored bacterial ooze can appear in advanced infections when tubers are gently squeezed. Arrow indicates examples of the ooze. Courtesy of Melinda Lent, research specialist, University of Idaho Department of Entomology, Plant Pathology, and Nematology.

Figure 4. External tuber symptoms of bacterial ring rot. Cracking of the skin may develop in advanced infections.

cell wall that retains crystal violet stain during a Gram stain test. Unlike many bacteria that cause potato soft rot and black leg, the bacterial ring rot pathogen is a vascular pathogen, colonizing the xylem of the plant.

Symptoms and Signs

Classic internal tuber symptoms include discoloration of the vascular tissue ring, visible when the tuber is cut crosswise or lengthwise (Figure 1). The name of the disease, ring rot, is derived from this symptom. In early infections, the discoloration may be slight, varying from light yellowish brown to dark brown, closer to the stolon end of the tuber (Figure 2). In more advanced infections, a cream-colored bacterial ooze, almost like processed cheese in consistency, exudes from the darkened vascular areas when the cut tuber is gently squeezed (Figure 3). As infections progress further, the vascular ring may develop hollow pockets and the ring may be surrounded by a

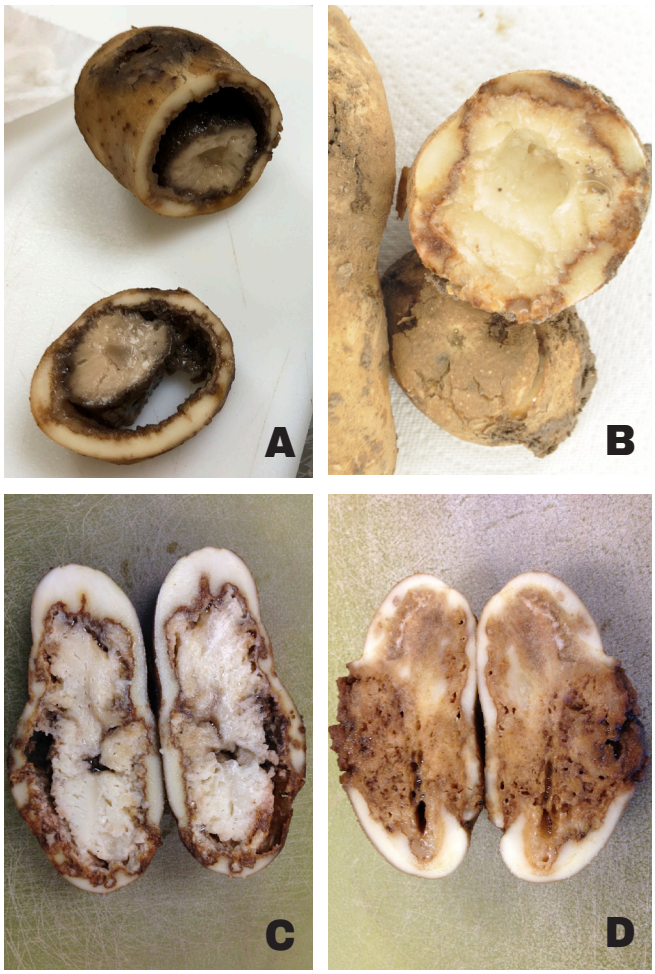

Figure 5. Mixed infections by pathogens such as soft rot bacteria (A), Pythium leak (B), or pink rot (C, D) mask typical bacterial ring rot symptoms.

Figure 6. Infection in tubers in the field can progress until only shells remain (upper right, indicated by white arrow).

Figure 7. A common symptom of a foliar wilt is known as "flagging," where a single stem here and there remains upright with wilted leaves. Since this symptom can be caused by other pathogens, a laboratory test is needed to confirm the cause.

dark, corky-brown layer. External symptoms on the tubers, such as surface cracks, may be observed in severely affected tubers (Figure 4). Mixed infections by pathogens such as soft rot bacteria, Pythium leak, or pink rot can also occur, masking the typical bacterial ring rot symptoms (Figure 5). If left in the ground long enough, symptomatic tubers often decay further, leaving empty tuber "shells" behind (Figure 6).

Aboveground foliar symptoms of bacterial ring rot resemble those associated with other foliar wilt diseases and, as in tuber symptoms, they are rarely diagnostic by themselves. Foliar symptoms appear as a progressive wilt that begins in the lower canopy usually around mid-to-late season. The wilt symptom occurs once the pathogen colonizes vascular tissue (the xylem) and produces abundant polysaccharides that block the vascular system and interfere with water uptake. Upward curling of leaves with **marginal necrosis** (dead, brown tissue along the leaf margins) becomes apparent as the wilt advances in severity (Figure 7). "Flagging," where only one or a couple stems wilt on a plant while other stems on the same plant remain apparently healthy, may also occur (Figure 8). Milder foliar symptoms can include pale green to yellow spots in areas between leaf veins, a symptom referred to as **interveinal chlorosis** (Figure 9). Less commonly, **interveinal necrosis** (dead areas between the veins) can be seen. Wilt symptoms can progress until the plant dies prematurely.

Figure 8. Bacterial ring rot may cause leaves to curl upward, with brown (necrotic) edges.

Figure 9. Discoloration between the veins (interveinal necrosis, top photo; or interveinal chlorosis, bottom photo) can occur with bacterial ring rot.

Table 1. Foliar symptoms of bacterial ring rot and incidence observed in a two-year study evaluating symptom expression of the disease.

Foliar symptom	Idaho % incidence	North Dakota % incidence
Interveinal chlorosis	56	36
Marginal necrosis	52	41
Wilt	30	9
Flagging	20	33
Interveinal necrosis	8	1
Early dwarf	2	55
Rosette	2	0
Twist of leaflets	2	33

Incidence refers to the number of plants (converted to a percentage) showing symptoms within a particular variety, location, or inoculation dose, across the two years of the study. Adapted from Whitworth et al. 2019.

The symptom type can be influenced by the potato variety and the environment where the crop is being grown. For example, in a recent two-year study examining foliar symptom expression of bacterial ring rot on twenty-five potato cultivars, symptoms varied from one location to another and from year to year (Table 1). The commonly observed foliar symptoms in Idaho were marginal leaf necrosis and interveinal chlorosis, while in North Dakota, the common foliar symptoms were dwarfing and marginal leaf necrosis. The symptom of overall plant dwarfing developed on all cultivars grown in North Dakota but only on one cultivar grown in Idaho. Marginal leaf necrosis never developed on three cultivars at either location (Table 2). The variability in foliar symptoms can add to the challenge of detecting the disease in the field and highlights the importance of a laboratory test to confirm the cause. Scouting for foliar symptoms is best done mid- to late season. At this point, in addition to the foliar symptoms, the stem can be removed and cut at the base (green/white interface) to look for symptoms. Squeezing the cut stem by hand or with a pair of pliers expresses plant sap and any associated bacteria (which appears as a white to cream-colored mass in the clear plant sap). The tubers can also

Table 2. Foliar symptoms of bacterial ring rot among twenty-five potato cultivars over two years in Idaho (ID) and North Dakota (ND).

	Early Dwarf		Marginal Necrosis		Interveinal chlorosis		Wilt		Flagging	
	ID	ND	ID	ND	ID	ND	ID	ND	ID	ND
Agata	*	*	*	X	*	*			*	X
Anuschka		*	*		*	*	*	*		X
Bintje	X	*		*	*					
Blue Belle		*				*				*
Cecile		X			*				*	
Challenger		X	*	*	*		X			
Ciklamen		X	*	X		*	X			X
Elfe		*	*		*	*	*			
Gala		X	*	X	X	*			*	*
Jelly		X		*	*		*			*
Maris Peer		*	*	*	*	*		*	*	*
Melody		*				X		*		*
Rosara		*	*	X	X					X
Victoria		*	*	X	*	X				*
Yukon Gem		*		*		*				*
Yukon Gold		*	*	X	*	*		*	*	X
Classic Russet		*	X	*	X	*		*	X	*
Clearwater Russet		*	*	*	X	*	*			
Mountain Gem Russet		X	X		X	*	*			*
Payette Russet		X	X	*	X	*	*			
Pomerelle Russet		X	X	*	X	X	*	*	*	X
Targhee Russet		*	*	*	*	X	*		*	*
Red Norland		*	X	X	X	*	*			*
Russet Burbank		*		X		X				*
Russet Norkotah		*	X	X	X	X	X		*	X

An asterisk (*) indicates that the symptom was observed in one year of the study and an "x" indicates the symptom was observed in both years. Adapted from Whitworth et al. 2019.

be examined and cut crossways near the stolon to expose the vascular ring. Gently squeezing this part of the tuber may expose vascular rot areas and the associated bacteria. However remember, all varieties are capable of harboring latent infections, where the pathogen is present in the plant without causing symptoms.

Important: Though some symptoms can be characteristic of a bacterial ring rot infection, confirmation must be made with a laboratory test.

Disease Cycle

The disease cycle of bacterial ring rot of potato (Figure 10) is complicated because of latent infections and the ability of the pathogen to survive for long periods as biofilms on equipment and in facilities. When tubers carrying the bacteria are cut into seed pieces, contaminated cutting knives can transfer the pathogen to healthy tubers. Pick-type planters can also spread the pathogen because the bacteria from infected tubers accumulate on the picks and the contaminated picks then inoculate healthy tubers.

During the growing season, the bacteria will spread up the stem from infected seed pieces and multiply in the stem tissue. The pathogen can reside in plant tissue as latent infections. Aboveground and belowground symptoms are rarely seen until late in the season. Plant-to-plant movement of the pathogen during the summer, for example by insects, is very low and its importance is not fully understood.

Ring rot bacteria spreads down the vascular system and infects daughter tubers as tubers start to bulk. These tubers may show a range of symptoms, from severe to latent. Tubers with severe symptoms may rot in the field before harvest or the infection may remain latent. Latent infections may lead to visible symptom development after tubers have been stored or after several generations of increasing seed potatoes in the field.

At harvest and during the loading of tubers into storage facilities, infected tubers may contaminate harvest and handling equipment, trucks, and surfaces in the potato cellar. Any healthy potatoes

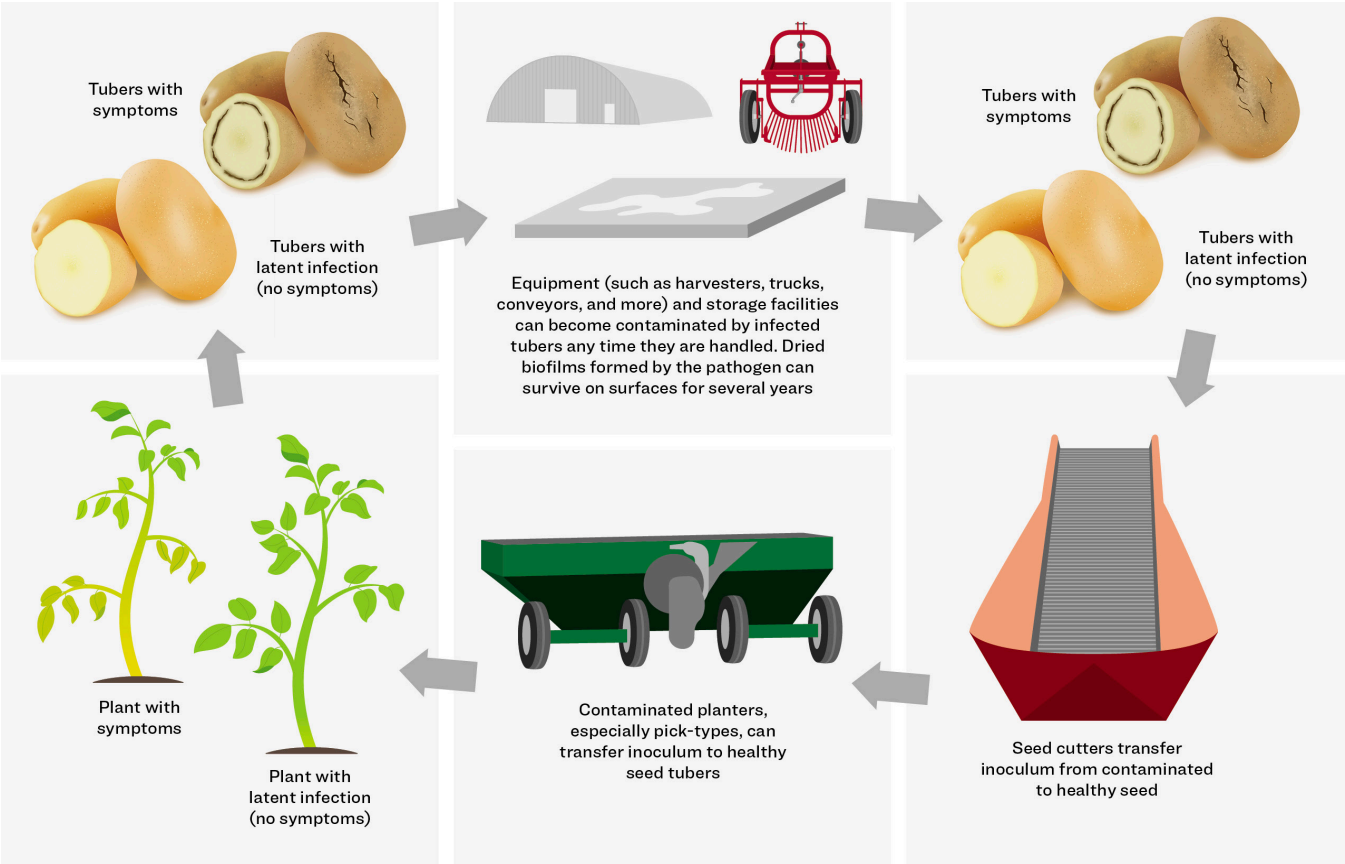

Figure 10. Disease cycle of bacterial ring rot. Designed by Lynna Stewart, University of Idaho Extension Publishing.

which have damaged skin due to bruises, cuts, and scrapes may become infected if the pathogen enters the vascular tissue of the healthy tuber. In addition, free water released from rotting potatoes allows secondary soft rot pathogens to enter a larger number of tubers and affect larger areas in storage.

The pathogen can survive from one season to another in plant debris that has not broken down and in infected tubers left in the field that emerge as volunteer potato plants the following growing season. The pathogen is not believed to survive very well in soil outside plant tissue. However, it produces large amounts of a slimy extracellular matrix made up of complex sugars. This extracellular substance dries to form a protective biofilm, allowing the bacteria to survive in a dried state for years on storage walls and ducts, handling equipment (such as cutters, planters, harvesters, sorters, conveyor belts, truck beds, potato sacks), and virtually any surface for up to five years under cool conditions with low relative humidity. Reuse of contaminated equipment risks spreading the pathogen once biofilms become reactivated with exposure to higher moisture, so sanitation is critical.

Management

Chemical Control

There are no fungicides or bactericides available to eliminate or manage bacterial ring rot in seed potatoes or in the field.

Prevention

The best way to manage bacterial ring rot is to keep the pathogen and disease off the farm. The first step is to use certified seed that has been tested in a laboratory for the presence of the bacterial ring rot pathogen.

Plant Certified Seed

Prevention starts with using seed potatoes that are pathogen-free. In the United States, all states have adopted certification standards with "zero tolerance" for the bacterial ring rot disease, which means that if just one infected plant or tuber is detected at any point during seed production (whether during the growing season, required postharvest testing, or shipping-point inspections), the entire seed lot is ineligible for certification. Even if a seed lot passes these tests and qualifies for certification, the status can still be removed if an infected tuber is found in any subsequent testing.

The Idaho seed potato certification program monitors for bacterial ring rot in the field during the growing season, in postharvest testing, and at shipping-point inspections. More information on the rules and regulations for bacterial ring rot and potato seed certification can be found in "Policies and Procedures for Certification of Potatoes in Idaho" (03/02/22), available online at: https://www.idahocrop.com/standards. Always request a Plant Health Certificate from the seed potato grower. This will indicate if bacterial ring rot was found on the farm that year or in the previous five.

Sanitation

Sanitation depends on the complete removal of the pathogen from all possibly contaminated surfaces on equipment, trucks, and in potato storages where infected tubers were stored. Good sanitation is critical to prevent contamination or infection of healthy seed lots. University of Idaho Extension Publication *Cleaning and Disinfecting Potato Equipment and Storage Facilities* (CIS 1180) discusses sanitation approaches in detail.

The initial step in sanitation is to clean any contaminated surfaces with soap and water as thoroughly as possible before applying any disinfectant. This step is essential, since soap is vital to breaking down the biofilms and biofilms tend to be more resistant to disinfectants. In addition, the presence of dirt or other organic matter can interfere with the effectiveness of a disinfectant.

Following a thorough cleaning and rinsing to break up the biofilms and remove any debris, use of a commercial disinfectant is helpful. Several are available, such as those containing quaternary ammonia, hypochlorite (such as bleach), iodine, phenolic compounds, hydrogen peroxide, peroxyacetic acid compounds, and chlorine dioxide. For all products, always read, understand, and follow label instructions. The general rule of thumb is to ensure that disinfectants remain wet and in contact with contaminated surfaces for at least ten minutes.

Monitoring for the Pathogen on Equipment and in Facilities

Once equipment has been cleaned and sanitized, a swab test is recommended to determine whether the pathogen is still present on the equipment and other surfaces after cleaning and disinfecting. A swab test consists of wiping sterilized cotton swabs on portions of cleaned and disinfected surfaces that might harbor the pathogen, then submitting them to a testing laboratory, such as University of Idaho Plant Diagnostic Services or the Idaho Crop Improvement Association. In some cases, even after several cleaning and disinfectant treatments, the pathogen may still be detected on equipment and building surfaces.

For both commercial and seed potato growers, it is strongly advised to avoid the use of any contaminated equipment or storages until a pathogen-free status can be verified, such as by the swab test as described above. Additional sanitizing is often necessary. In some cases, the best course of action may be to replace contaminated components of equipment.

Volunteer Potato and Cull Pile Management

In fields where bacterial ring rot has been found, it is critical to monitor and destroy volunteer potatoes the following season. Such volunteers may harbor the pathogen and recontaminate equipment. Cull piles from fields where bacterial ring rot occurred should also be destroyed and any equipment used in that process should be sanitized as described above. More information is available in Cull and Waste Potato Management (CIS 814).

Resistant Varieties

No commercial varieties resistant to bacterial ring rot are currently available.

Important Management Tips

Minimizing Bacterial Ring Rot Risk

- Always use certified seed.
- Avoid mixing seed lots when cutting and store lots separately after cutting. Track where seed lots are planted in the field and avoid mixing seed lots when planting.
- During seed cutting, disinfect the knives often. Thoroughly wash and sanitize cutters between seed lots.

What Should You Do If Bacterial Ring Rot Appears?

- If ring rot is found on seed tubers before cutting or planting, DO NOT plant the seed.
- If ring rot was linked to seed you are in the process of planting or have finished planting, DO NOT plant any remaining seed. Clean all seed-hauling, cutting, and planting equipment prior to planting another seed lot.
- If seed from an infected seed lot has already been planted, monitor the area of the field in which the infected seed was planted for erratic emergence.
    - If poor stands are apparent and suspected to be due to seed decay, use good sanitation practices when evaluating the decayed seed. Use disposable gloves and consider covering your boots with disposable plastic boot covers. Remove the boot covers and replace with clean ones prior to entering another field. Disinfect knives and shovels between fields. Isopropyl alcohol works well for this purpose.
- Scout any fields planted to known infected seed for foliar and tuber symptoms of bacterial ring rot.
- If symptoms are detected in the field and confirmed by a diagnostic laboratory test, there are several different actions that can be taken depending upon the situation:

    Option 1: Harvest the infected field last and heavily pick out infected tubers prior to storing them. This approach allows more infected tubers to decay in the field and prevents use of contaminated windrowers and harvesters on healthy fields.

    Option 2: Mitigate the risk of further contamination and disease development by disking field. This option may be suitable for a seed potato grower, where risk of contaminating harvest equipment and

storage facilities is too great. Remember to thoroughly clean and disinfect the equipment used in this operation.

Option 3: For commercial growers who can capitalize on an early market, negotiating a means to harvest the crop early for direct delivery prior to additional crop losses due to decay may be a viable option. This option removes the storage facilities from a high risk of contamination.

- If harvested tubers from an affected field are to be stored:
  - Avoid harvesting infected fields with higher pulp temperatures. This will help in maintaining lower initial temperatures in storage which will slow the development of infection.
  - Early storage management recommendations include removing field heat as soon as possible, curing at 50°F–55°F, and then ramping down the temperature to conditions appropriate for the variety and its use. The goal is to maintain the market quality of the healthy potatoes. Reduction in humidity may be necessary but will depend upon the severity of the disease.
  - Tubers with symptoms and those with damaged skins should not be stored or stored for as short a time as possible. Cool storage temperatures can help to slow symptom development. However, symptoms can still develop in storage. Tuber-to-tuber spread of the bacterial ring rot pathogen in storages is considered rare, but damaged tubers can be vulnerable to secondary infection by soft rot organisms and it is the risk of such secondary infection that adds to the challenge of storing potatoes with bacterial ring rot. Monitor and remove them from storage if secondary breakdown starts to occur.
- In the field, rotate out of potato for at least three years, preferably longer, because the pathogen can survive from year to year in volunteer potatoes. A longer rotation is preferable to ensure destruction of volunteer potatoes. Increased attention should also be given to the implementation of effective control practices to remove any potentially infected volunteer potato plants that survive the winter.
- Rigorously clean and disinfect all equipment and storage surfaces that have contacted contaminated tubers. Eliminate the bacterial ring rot pathogen from the operation using thorough sanitation practices, testing for presence of the pathogen, and retesting. Retire contaminated equipment from operations if the equipment cannot be successfully cleaned.
- Pay close attention to fields where infection has been observed. Scout diligently for the pathogen in subsequent potato crops and volunteer potatoes in other crops.
- For seed growers: seed lots that have been confirmed positive for the pathogen along with contact seed lots are ineligible for recertification. That is, they cannot be planted to produce another generation of seed potatoes. In this manner, a complete flushing out of any confirmed and potentially contaminated seed lots from the system is achieved. Furthermore, although the compromised crop can be sold for commercial use (table, fry, flake, etc.), it cannot legally be used as seed.
- Be especially cautious when purchasing used equipment. Test any equipment for presence of the bacterial ring rot pathogen.

Use Caution When Determining the Source of Bacterial Ring Rot

Because of the importance of potato bacterial ring rot and the zero-tolerance policy of seed-certification programs, adopt great care and sensitivity when dealing with suspected cases. Confirm any suspected infections with a laboratory test, since other diseases resemble bacterial ring rot. In addition, document the chain of custody of the seed before it reaches your farm, since contamination of pathogen-free seed potatoes can occur at many points along the transit chain. If a commercial or seed farm has had a history of bacterial ring rot, healthy seed can

be inadvertently contaminated by biofilms of the pathogen from prior years. Correctly identifying the source of a bacterial ring rot problem—whether from infected seed or from contact with contaminated surfaces—helps inform a bacterial ring rot management strategy.

For More Information

Idaho Potato Certification Standards and Potato Policies and Procedures (3/2/2022) https://www.idahocrop.com/standards.

Cleaning and Disinfecting Potato Equipment and Storage Facilities (University of Idaho Extension CIS 1180), available online at http://www.extension.uidaho.edu/publishing/pdf/CIS/CIS1180.pdf.

Cull and Waste Potato Management (University of Idaho Extension CIS 814), available online at https://www.extension.uidaho.edu/publishing/pdf/CIS/CIS0814.pdf.

Sanitation for Bacterial Ring Rot, a Plant Management Network Focus on Potato Webinar available here: http://www.plantmanagementnetwork.org/edcenter/seminars/potato/Sanitation/presentation.html).

Bacterial Ring Rot of Potato webinar (The American Phytopathological Society (via Grow—Plant Health Exchange) available at https://www.plantmanagementnetwork.org/edcenter/seminars/potato/BRR/.

Further Reading

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