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Fig. 1. Tuber after removal from the mist chamber. The areas removed from the tuber were decayed by bacteria. This is the method used to determine the Soft Rot Potential Index (SRPI).

The Blackleg-Soft Rot Disease Complex in Potatoes

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Blackleg and soft rot of potatoes appear to be a complex of diseases in which several bacterial species may induce various foliar or tuber symptoms depending on environmental stress. At least four species or subspecies of bacteria are associated with soft rot of tubers in the northern U.S. potato producing areas. They include:

- *Erwinia carotovora* var. *carotovora* (Ecc)
- *Erwinia carotovora* var. *atroseptica* (Eca)
- *Pseudomonas marginalis*
- *Clostridium* sp.

Those bacteria shown to induce foliar symptoms in the U.S. are Ecc and Eca. In the Northwest, Eca is normally isolated from plants with typical blackleg symptoms while Ecc has been associated with foliar symptoms that are not considered to be typical of blackleg. The bacterial soft rots commonly occur in conjunction with other rots such as ring rot and *Fusarium* seed piece decay.

Symptom Description — Tuber

1. **Blackleg** — Infection of daughter tubers of a plant with foliar blackleg symptoms generally occurs at the stem end of the tubers. A sunken, dark, moist rot develops that can penetrate to the center of the tuber giving a dark, mush appearance to the tuber's core. Often, only the tuber's shell remains. These symptoms can occur in the field or in storage.

2. **Soft rot** — Symptoms, other than the dark, moist rot associated with plants with blackleg, are considered to be those of soft rot. These include a soft, white-yellow rot often with a dark margin. A bacterial slime will ooze out of lesions on the tuber if the "skin" is broken. If the skin is intact, the lesion can be detected by locating a soft area under the skin. The rot may be extensive, sometimes destroying more than half of the tuber tissue.

Seed pieces are often destroyed by soft rot, particularly when it develops on the fresh-cut surface. The rot may occur under the suberized cut surface and can destroy the entire seed piece.

Symptom Description — Foliar

1. **Typical blackleg** — Symptoms include soft, black, mushy lesions found anywhere on the stem below as well as above the soil line; chlorotic leaflets may be severely rolled, wilted, with eventual necrosis and a collapse of the stem, causing death.

2. **Atypical blackleg** — Stem symptoms range from a slight discoloration of the pith area to black, hard lesions anywhere on the stems. Stems may become mushy without the typical symptoms associated with blackleg. Early, atypical blackleg symptoms may suggest infection by the ring rot bacterium, but both can be diagnosed by experienced fieldmen and/or laboratory techniques.

Symptom Development

Symptoms of blackleg and soft rot are influenced by the tissue that is infected, the time at which symptoms develop and the environmental stress to which the plant has been exposed. Early in the growing season, seed pieces may rot; young plants or some of the stems may collapse and die. The amount of inoculum in or on the seed tubers will, depending on soil moisture and temperature, affect symptom severity in the plants. Under some environmental conditions, symptoms may not be expressed even though inoculum is present. These symptoms range from seed piece decay to early plant death to typical or "atypical" blackleg symptoms. Foliage symptoms may develop independent of tuber decay. Soft rot decay in storage is influenced by how the tubers are handled at harvest and by storage conditions — especially humidity and temperature — during the healing or curing period after harvest. Bacterial soft rot symptoms can be confused with other types of soft rots such as water rot and leak. They often occur as a complex with *Fusarium* rots.

Rot Development in Tubers

Bruises and other wounds are not necessary for infection to occur. However, if present, they will hasten infection by immediately providing a suitable environment in which the bacteria can multiply. The following sequence of events probably occurs when bacteria infest tubers:

1. Bacteria enter and survive in the lenticels.
2. Excess moisture causes lenticel cells to enlarge and separate, leaving exposed interior cells and spaces between cells.
3. Excessive moisture also causes a cellular oxygen deficiency to occur that alters membrane permeability; nutrients and water "leak" from cells into intercellular spaces.
4. The separation of the enlarging cells provides a point of entry for the bacteria and access to the nutrients and water in the intercellular spaces.
5. In this suitable environment, bacteria reproduce and release pectolytic enzymes that destroy the pectate-rich, middle lamella which serves as a glue to bind the cells together.
6. Tissue disintegration — ROT — occurs.

Wounds can replace the stress caused by excessive moisture. Crushed cells provide a point of entry for the bacteria and the necessary nutrients and water for infection, multiplication and intercellular movement in the tuber.

Symptom Development in Foliage — Blackleg and Soft Rot

1. Bacteria in or on the seed piece cause it to rot.
2. Bacteria move intercellularly up the stem, causing disintegration of the tissue.
3. The dark, mushy stem symptom may develop or chlorosis and wilting of the apical leaflets may be the first symptom followed by additional chlorosis, wilting and death of leaves and stems.
4. Isolated foliar symptoms of stem lesions, leaflet chlorosis, rolling and wilting may occur in plants adjacent to the systemically infected one. This probably occurs from aerosol or insect dispersal of bacteria from plants with the blackleg symptoms.

Fig. 2. Foliage symptoms caused by bacterial soft rot.

Fig. 3. Potato plant wilting because of blackleg.

Bacterial Survival

Until recently, *Erwinia* bacteria were not considered capable of overwintering in soils of northern potato-producing areas of the U.S. However, studies using special culturing techniques have shown that the bacteria can overwinter in soil from Wisconsin and Oregon but at low population levels. Recent studies in Colorado have found these bacteria to be present in surface water. Despite demonstrated ability to survive in the soil and surface water, it is likely the primary means of survival and major sources of inocula are the seed tubers. The bacteria survive in the lenticels, and the resident bacteria establish an intimate and stable relationship with the tuber. Vigorous scrubbing under running water will not remove the bacteria.

The tuber infecting *Pseudomonas* sp. can be recovered in the spring from soils in which potatoes were grown the previous year without special culturing techniques. They may also survive in the lenticels of tubers. In Wisconsin, *Pseudomonas* sp. were recovered from a greater percentage of tubers than *Erwinia* sp., and studies conducted in Idaho indicate that *Pseudomonas* sp. bacteria survive storage better than *Erwinia* sp. do. The relative importance of the lenticel, tuber-borne and soil-borne sources of *Pseudomonas* sp. in the disease has not been determined.

Transmission of Bacteria Among Tubers and Plants

Spread or transmission of soft rot and blackleg bacteria among tubers and plants can occur in several ways depending on the location of plants, time of year, movement of free water down the furrow, level of tissue contamination and availability of vectors and inocula. The ways in which transmission can occur among tubers and plants are:

(1) Tuber to tuber contact, (2) tuber and plant contact with contaminated surfaces, (3) seed cutting, (4) seed piece to foliage, (5) seed piece to daughter tubers, (6) plant to plant by insects, (7) plant to plant by aerosols (rain or sprinklers) and (8) tuber to tuber by aerosols (humidified ventilating systems).

Tuber-Bacteria Interactions in Storage

Tubers have been shown to have different susceptibilities to soft rot bacteria, depending on variety, extent and rate of wound healing and maturity or physiological condition at harvest. The potential for soft rot development in potatoes can be determined by subjecting tubers to moisture and temperature stress in a mist chamber. The soft rot potential index (SRPI) determined by this method considers the proportion of tubers with soft rot and the severity of decay in individual tubers. Investigations in 1980 have shown that the potential for soft rot is highest in the period following harvest and declines as the storage period progresses (Table 1).

During storage, populations of bacteria-contaminating tubers decline rather dramatically. Studies in western Canada indicate that if 90 percent of the tubers in storage were contaminated with *Erwinia* sp. bacteria at the beginning of the storage period, only 33 percent of the tubers were found to be contaminated 5 months later. Investigations in Idaho indicate that in 30 days, from early December to early January, the populations of soft rot bacteria in or on tubers declined about 40 percent. This indicates that if tuber bacterial populations are high in the spring, the tubers must have been heavily contaminated when placed into storage.

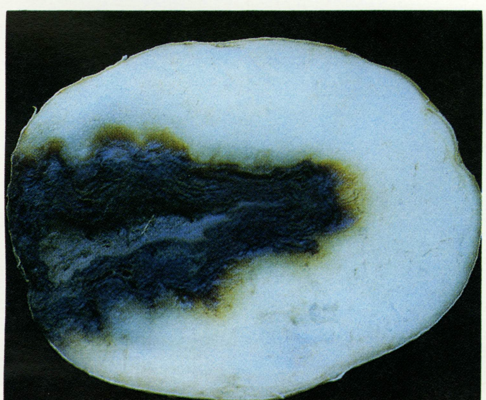

Fig. 4. Tuber symptoms of blackleg.

Fig. 5. Internal stem symptoms of blackleg.

Fig. 6. External stem symptoms of blackleg.

Table 1. Summary of soft rot potentials in Idaho seed potatoes, 1980-81: tuber condition - location - storage interval.

Variety	Mature Field	Harvest Storage	3-5 weeks Storage	7-9 weeks Storage	17 weeks Storage
Russet Burbank — Not Bruised					
% SR[1]	0.6	2.9	16.7	3.5	3.8
SRPI[2]	0.001	0.018	0.071	0.004	0.004
Russet Burbank — Bruised					
% SR	2.5	8.9	28.3	21.2	15.9
SRPI	0.014	0.051	0.143	0.071	0.075
Lemhi — Not Bruised					
% SR	6.1	28.3	35.4	7.8	15.3
SRPI	0.020	0.564	0.221	0.024	0.103
Lemhi — Bruised					
% SR	13.2	32.1	54.6	29.0	28.8
SRPI	0.080	0.640	0.493	0.222	0.218

[1]% SR - % tubers with soft rot lesions

$$^{2}\text{SRPI} = \frac{\text{\# tubers with soft rot lesions}}{\text{\# tubers tested}} \times \frac{\text{total \% weight loss of tubers with soft rot}}{\text{\# tubers tested}}$$

Control of Blackleg and Soft Rot Diseases

The control methods for blackleg and soft rot include excluding the bacteria from the potatoes or altering the tuber or seed piece structurally or physiologically to reduce susceptibility to the blackleg-soft rot bacteria. The exclusion of bacteria from the crop can partially be accomplished by planting tubers free of or with small populations of the blackleg-soft rot bacteria. Ways to do this include:

1. Plant seed known to be free of obvious blackleg and tuber soft rot in the previous growing season and storage period.
2. Plant seed potatoes derived from a stem-cutting program. Keep your seed lots separated, and plant the best quality seed first. Carefully clean and disinfect handling and planting equipment between each seed lot.
3. Plant seed potatoes tested for their soft rot potential — use seed lots with a consistently low SRPI.
4. Plant single drop seed if possible.

Tubers or seed pieces may be altered structurally or physiologically to become less susceptible to soft rot decay when in storage or as freshly cut seed. One possibility is to warm the seed potatoes at 65 to 70°F for 3 to 7 days just before cutting and planting. Table 2 summarizes what can happen to soft rot potential of tubers treated in this manner.

A practical approach to soft rot control in seed potatoes that are to be planted as cut seed is to precut the seed and allow it — with temperature, air and humidity management — to thoroughly suberize and heal the cut surfaces before planting.

Table 2. Temperature conditioning of whole seed tubers and change in Soft Rot Potential Index (SRPI).

Temperature	Reconditioning periods (days) 0	5	7	9
Storage (40-42°F)	0.6	0.5	0.5	1.2
45°F	—	0.6	0.6	1.6
55°F	—	0.2	0.1	0
65°F	—	0.1	0.1	0

1. Precut and suberize seed, allowing the piles to reach 50°F for 3 to 6 days, with high humidity and moving air.
2. After a suberizing period, lower the temperature of the cut seed to 40°F until 7 to 10 days before planting.

Reduced susceptibility to bacterial soft rot decay can begin in 6 to 10 days. After 3 weeks, the cut seed potatoes may have a SRPI lower than that of the whole tubers before cutting.

Table 3. Changes in soft rot potentials in precut seed potatoes.

Interval between cutting and SRPI test (days): whole tubers 0	cut tubers 0	1-5	6-10	11-15	15-23
% Tubers or Seed Pieces with Soft Rot					
6.8	60.0	74.3	30.7	47.1	3.6
% SRPI					
0.04	6.50	8.50	3.00	1.36	0.01

Harvest and Crop Storage

1. Begin harvest only after the vines are thoroughly dead and tubers are mature. Do not harvest potatoes when the tuber pulp temperature is below 45°F. This will reduce bruise damage and reduce the points of entry for soft rot bacteria and dry rot fungi.

2. Operate harvest and storage handling equipment so that bruising is minimized. Clean and disinfect the equipment between seed lots and harvest lots in order of quality, with the best first. Clean and disinfect storage areas before harvest.

3. Operate fans and humidifiers in storage during the first 6 to 8 weeks to maximize the wound healing process; maintain temperature at 55°F for 10 to 14 days and then gradually lower to the appropriate storage temperature with the relative humidity above 95 percent. Avoid condensation dripping onto potatoes to prevent establishing an environment that can induce blackleg and soft rot bacteria to begin multiplying and cause tuber soft rot.

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