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Impact of Freezing Temperatures on Potato Tubers

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Introduction

ALTHOUGH RELATIVELY UNCOMMON in Idaho's climate, freezing conditions occasionally occur during harvest while potatoes are still in the ground. Tubers might develop quality defects or freeze entirely, risking irreversible and permanent damage from crystallized water molecules that injure cell walls and tissues. In extreme cases, severely affected tubers may need to be left in the field unharvested. Otherwise, they might decay and/or physically break down during the storage season. Beyond direct losses due to decay, secondary concerns include the indirect effects of freezing or low-temperature exposure on the color of processing potatoes and seed quality. This guide helps identify chilling and freezing injuries, enabling more effective management of the affected crop.

Freezing Injury

Although water freezes at 32°F, the freezing tolerance of a potato tuber is lower than 32°F due to the diluted mixture of water with soluble minerals and sugars within the cells. A tuber's freezing point depends on the cultivar, rate of decline in temperature, final tuber temperature, and duration of exposure to low temperatures. Freezing of potatoes often starts between 27°F and 29°F, with injury appearing in the first few hours at 27°F. The extent of the injury depends on the length of the potatoes' exposure to damaging temperatures.

Symptoms of freezing may become apparent only after the tubers begin to thaw. Frozen potatoes exhibit wet, shiny skin, followed by a deteriorating appearance over time. At this point, the tuber tissue shrivels and weeps liquid and the skin may show signs of cracking (Figure 1). Once frozen tubers are taken into storage and given the opportunity to warm, breakdown of the tissues can occur. As the tubers thaw, water within and around their cells flows freely out of the potato and onto nearby tubers. The excess moisture can lead

to further decay throughout a stored pile. Frozen potatoes release a substantial amount of liquid when thawing, as shown in Figure 2, necessitating additional management measures in storage.

When completely frozen, a 6-ounce potato releases about 2.4 ounces of liquid in the first twenty-four hours as it thaws at room temperature (Figure 3). Indeed, a considerable amount of liquid produced from frozen potatoes must be managed in storage to avoid further complications. The high levels of free moisture released onto potato tubers after thawing increase the risk of infection by pectolytic bacteria that cause soft rot decay, leading to further breakdown of the stored crop. Internal symptoms of freezing damage can range from off-white to grey or blackened tissues affecting small to large areas of the potato (Figure 4). Frozen tissue has an exceptionally soft, mushy texture due to the loss of cellular structure. Once this portion sloughs off, the remaining healthy tissue may begin to heal the resulting wound, but only if the tuber remains free of bacterial soft rot.

Increased ventilation, reduced humidification, and condensation management help to dry out the pile, minimizing further breakdown of the healthy and unfrozen potatoes that remain in storage.

Figure 2. Frozen potatoes thawing out in storage can create wet spots or areas that need additional management to dry out the entire pile.

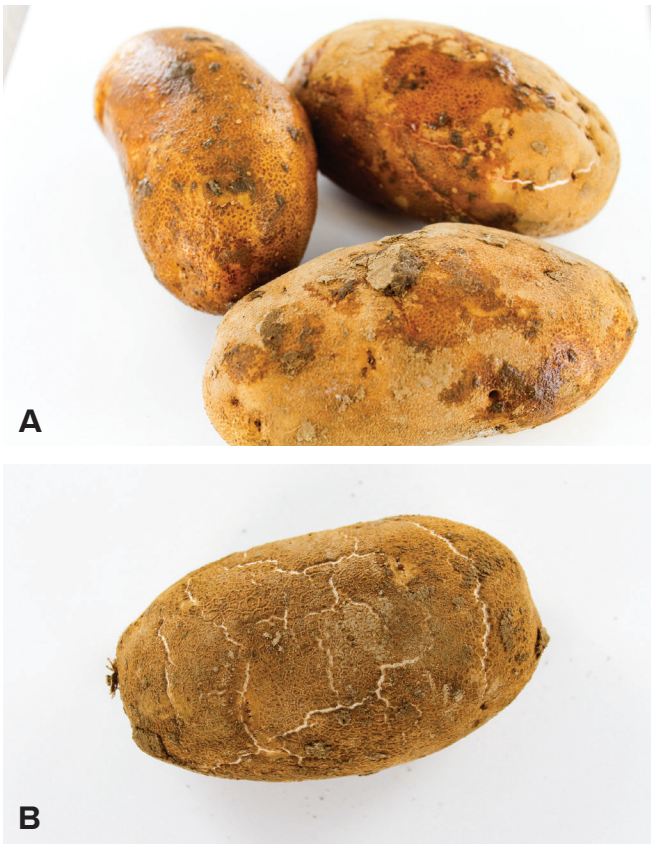

Figure 1. **A**, Liquid weeping from frozen potatoes creates condensation or free moisture on the skin. **B**, The freezing process produces breaks in the skin due to water expansion when freezing.

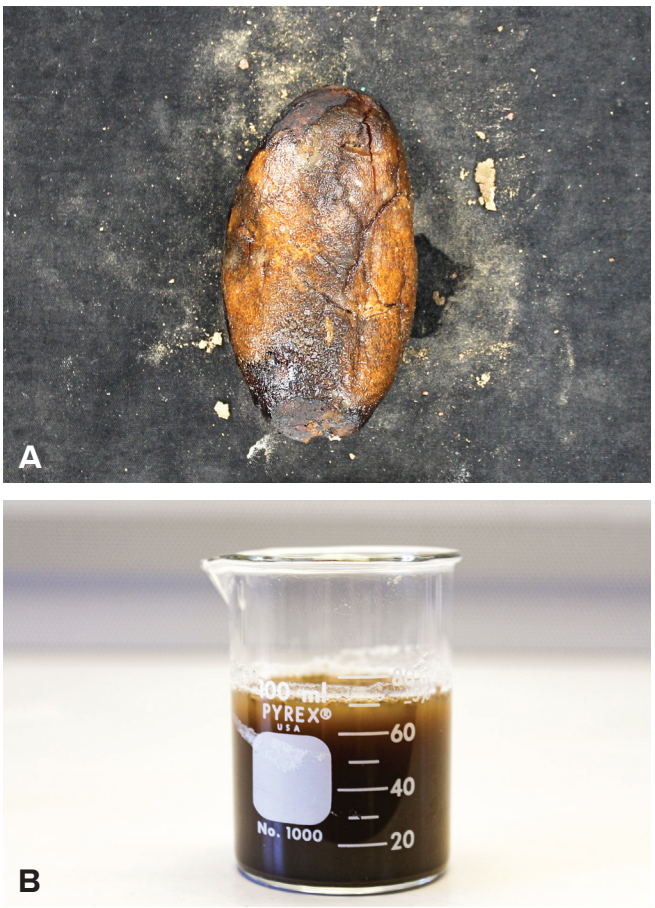

Figure 3. **A** and **B**, A single 6-ounce potato can expel up to 2.4 oz of liquid within twenty-four hours when thawing at room temperature.

Sometimes only part of the potato freezes. This may happen if a portion of the tuber, often the bud end, is closer to the soil surface. If only part of the tuber freezes, a distinct line between frozen and healthy tissue is initially visible (Figure 5). Deeper soil profiles offer some protection from freezing injury, due to the cold temperatures taking longer to penetrate the soil. However, tubers in a deeper soil profile may still experience chilling injury.

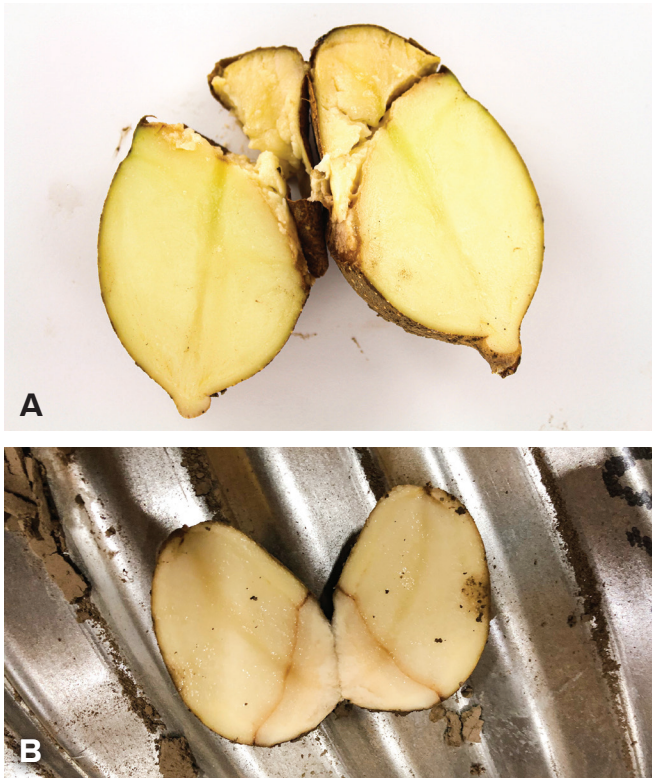

Figure 4. A, Tissue separation (sluffing) of frozen tissue from healthy tissue with a distinct line, B, often darkened, across the internal tissue.

Figure 5. Freezing symptoms seen on the bud end of the tuber. The skin and associated tissues are damaged and create a darkened area as tissues oxidize.

Chilling Injury

Internal damage of potato tubers due to cold temperatures can begin at temperatures as high as 37°F. Chilling injury may not result in the death of a tuber; however, the severity of internal damage gradually increases as temperatures drop below freezing. Injury may be present after as little as twelve hours when exposed to 28°F, while it may take weeks or even months to develop symptoms at temperatures of 32°F or above. Chilling injury occurs in a potato tuber as an off-white to pink discoloration with grey- or black-speckled blemishes or cavitations, primarily in the outer ring of tissue closest to the skin (Figure 6).

Figure 6. A–D, Potatoes with chilling injury exhibit a range of internal tissue damage; some with off-white color and others with grey and blackened areas and cavities.

Freezing Injury Versus Chilling Injury: How to Tell the Difference

Freezing

External Symptoms: water release; wet, shiny skin, followed by cracking

Internal Symptoms: soft, mushy tissue, off-white to grey or blackened; thin line divides frozen from healthy tissue

Chilling

External Symptoms: no water release

Internal Symptoms: no tissue disintegration, but exhibits off-white to pink discoloration, with grey- or black-speckled blemishes/cavitations

Chilling injury is primarily an internal defect that is not associated with water release since internal tissues remain intact and do not disintegrate, as seen with freezing injury. In severe cases, cavitation and speckled blemishes extend deep into a tuber's center or pith. These internal symptoms are considered a defect and at high incidences could impact commercial acceptance of the potatoes. Chilled potatoes, with or without injury symptoms, may exhibit undesirable processing quality due to the potential for higher reducing-sugar content and darker fry color. In some cases, potato tubers exposed to chilling temperatures and low light levels may also exhibit pink flecks or rays in the tissue of the tuber. The discoloration is due to anthocyanin production (Figure 7).

Planting a Seed Crop Previously Exposed to Freezing Temperatures

Seed potato crops harvested late in the previous season may experience freezing temperatures that could negatively impact the survivability and vigor of the seed tubers for planting the following season. A three-year study conducted at the University of Idaho evaluated the response of Clearwater Russet and Russet Burbank seed potatoes to freezing temperatures. Tubers of the two varieties were exposed to air temperatures of 28°F or 29°F for 6–16 hours after harvest, then stored over the winter using conventional practices (40°F; 95% relative humidity). The treated (exposed to freezing temperatures) and nontreated (constant 40°F exposure) seed tubers were then planted the following spring and evaluated for growth, yield, and tuber size profile. Under the conditions of this study, no negative impacts were observed on seed pieces with respect to emergence, stems per plant, yield, and tuber size.

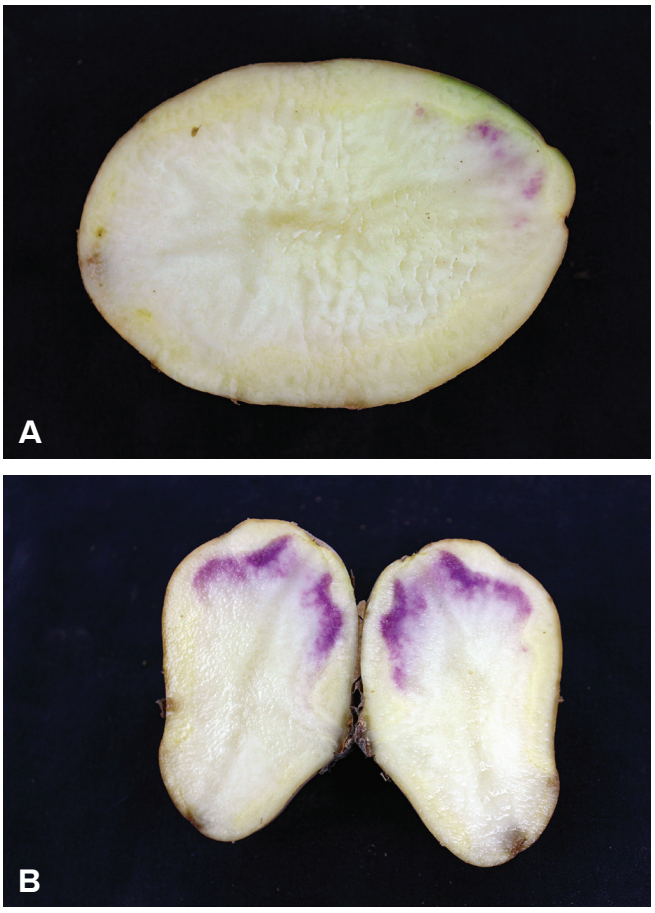

Figure 7. **A** and **B**, Pink-to-purple flecks or rays in the tissue of a potato exposed to chilling temperatures and low light levels. Anthocyanin production, prevalent in certain varieties, causes the discoloration.

Management Practices

When weather events turn cold during the harvest season, look for signs of freezing potatoes. The presence of frozen potatoes suggests that other tubers may have chilling injury. Identification of the problem early is crucial for harvest and storage management decisions.

Knowing how to identify crop injury related to cold temperatures aids in management decisions. Signs of frozen tissue appear after tubers have thawed. Situations that involve storing a percentage of frozen potatoes need to be managed for potential soft-rot breakdown. The threshold to safely manage affected tubers is generally recommended to be no more than 3%– 5% freezing injury within a pile.

If frozen potatoes must be stored, consider available storage options and try to avoid sharing a plenum or storage bay with nonfrozen and sound potatoes. Managing frozen potatoes in storage needs to be assessed in a case-by-case manner, given that some of the management strategies affect healthy potatoes. Key strategies include reducing humidification, using heaters at the top of the pile to minimize the potential for condensation, utilizing high ventilation rates to help exhaust excess water, and dropping temperatures to a range that still provides acceptable market use of the remaining healthy tubers.

Though chilling injury is considered less serious than freezing injury, it can produce a range of internal symptoms that may downgrade the quality of a crop and is also associated with high reducing sugars and dark fry color.

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