Understanding Cranberry Frost Hardiness

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The threat of frost is an important limiting factor in the production of cranberries in Wisconsin. Although there is no month free from the possibility of frost, we know that spring and fall are the most critical times of the year. In spring the plants are vulnerable after the pulling of the winter flood and as they begin to grow under favorable conditions. In the fall the threat of frost limits the length of time the berries can be left on the vines to develop maximum color. Irrigation pipes are removed prior to harvest, thus, prior to making ice cover for the winter, reflooding is the only frost protection method available. Reflooding is expensive and is not always feasible.

Despite the reality of the importance of frost protection, there is a sense among growers and managers that the crop is typically "overprotected" by the initiation of overhead sprinklers at relatively warm temperatures. This is understandable due to the high value of cranberries and the current lack of understanding about the hardiness levels of the plant throughout the year. Our goal is to provide recommendations for more efficient frost protection strategies; to help growers save money, energy, and water.

Bud stage terminology

When we started our work in 1995, we focused on sampling weekly and performing hardiness tests in our laboratory. We observed dramatic changes in the hardiness of buds and leaves; from surviving temperatures less than 0°F when the flood was first removed in the early spring, to only being able to handle temperatures around 32°F when the new growth emerged. At this time we saw that we needed to be able to refer to the various stages of growth that occurred between these extremes in hardiness. This had important implications for the sampling for our freezing tests as several stages would be present in a bed at a given time. With input from growers and other researchers we, with Teryl Roper's help, defined eight stages of bud development. **An illustrated article containing details on bud development and bud terminology will appear in the February 1997 issue of *Cranberries* magazine.** Aside from use in our own work, we hope this terminology will be useful to growers and others studying other aspects of cranberry growth and development. The eight stages are: 1) tight bud; 2) bud swell; 3) cabbagehead; 4) bud break; 5) bud elongation; 6) rough neck; 7) hook; and 8) bloom. Table 1 gives a brief description of each stage.

The 1996 growing season

Development of protocols for assessing frost hardiness of various parts of the cranberry plant:

This past season we sampled 'Stevens' uprights from the Nekoosa area from mid-April to mid-October, with the last sample date being just prior to harvest. Random samples were collected from six areas of the bed using a 1O"x10" square frame. After transport to Madison on ice, the samples were sorted by bud stage. The most numerous advanced bud stage was used for hardiness testing in order to characterize the most vulnerable yet also the most meaningful stage at each date. The uprights from the selected stage were then cut to approximately 4 inches and put in large test tubes., which in turn were placed in a large circulating glycol bath. The bath was lowered through a series of freezing temperatures at intervals of 1 to 3.5°F every half hour. A small piece of ice was added to each tube at about 30°F to assure uniform ice formation across all of the tubes. Samples were removed from the bath as particular temperatures were reached.

After the samples thawed overnight, they were held for five days at 39°F for any recovery to occur. **Damage from the freezing stress was evaluated in three ways: visual scoring of browning and water-soaking, ion leakage measurements, and observation of the uprights' abilities to root and regrow.** A water-soaked appearance in leaves, buds, and flower parts are visual signs of damage. Damage to the interiors of buds and flowers are observed by dissecting these to look for further signs of water-soaking and browning. When cells in plant tissue are injured by stresses, such as chilling and freezing temperatures, parts of the cells' membranes are weakened. This affects their ability to retain the cells' contents, such as ions like potassium. The amount of leakage, and hence injury, can be assessed by soaking pieces of the tissue in distilled water and then measuring the electrical conductivity of that water. Regrowth studies entail monitoring the ability of terminal and axillary buds and adventitious roots to grow after exposure to different freezing temperatures.

Results to date:

Since there are no economic thresholds defined for frost damage, the results from **these freezing** experiments are summarized **as the lowest survival temperatures (LST)** for the different plant parts. This is the **lowest temperature at which all of the tissue of a particular plant part survived. These results are preliminary, and should not be considered as a recommendation regarding frost protection practices.**

Leaves developed during the previous growing season (old leaves) were initially very hardy in the early spring after the pulling of the winter flood (Figure 1). At this time of the year, old leaves were able to survive temperatures of about 0°F to about 10°F. With the beginning of new growth in early June, the hardiness of old leaves had decreased to about 32°F. A significant loss of hardiness occurred between the May 13 and May 20 sample dates. This is likely due to the plants' response to the warming springtime temperatures (Figure 3). New leaves were initially very sensitive to freezing temperatures, only being able to survive temperatures around 30°F. This sensitivity is due the lack of a thick waxy cuticle and possibly the lack of certain substances, such as suberin and lignin, in the cells of those new leaves. By late summer the new leaves were able to survive temperatures about 20°F and by the beginning of October they had hardened to about 10°F.

The lowest survival temperatures of buds, flowers, and fruits are shown in Figure 2. Buds showed significant changes in hardiness from early spring, at the tight bud stage, to bud break. At the tight bud stage, buds survived temperatures as low as - 10°F. Buds from the first two samples were rated as being significantly less hardy (around 10°F). **This is likely due to a high incidence of pre-existing bud damage in the bed. These damaged buds had green healthy-looking bud scales, but were brown and dead on the inside.** By the time of bud break, the new growth was only able to withstand temperatures around 32°F. Between these two extremes of both development and hardiness several significant changes were observed. As seen in the old leaves, a dramatic loss in hardiness also occurred in the buds between the May 13 (about -5°F) and May 20 (about 13°F) samples. However, between these two sampling dates the most numerous bud stage remained the bud swell stage. This further supports the idea that the plants were deacclimating from their hardier state in response to the warmer field temperatures (Figure 3). Another notable change in hardiness was also seen the following week (May 27) as the next bud stage, cabbagehead, had an LST of only around 26°F.

As expected, flowers were extremely sensitive, only being able to survive temperatures around 30°F. Green fruits of all sizes were sampled in late July and mid-August and were very sensitive, with no damage only occurring at temperatures between 32 and 30°F. By early October, **when the fruits were greater than 75% blush, they were able to experience temperatures about 23°F with no damage.**

These preliminary data are a baseline upon which our further work will be based. Just as some questions about the hardiness of different plant parts are beginning to be answered, many new questions also **arise. Some of these additional areas of inquiry include issues such as the impact of pre-existing bud damage levels on hardiness determination, the effect of the duration of freezing temperatures on hardiness, and the possible importance of hardiness of different flower parts (pollen, ovary, style) to fruit set.** Pre-existing bud damage may be responsible for the lower initial hardiness ratings of the buds from our first samples. Potential sources of damage include harvest, flooding, and winter stresses. Systematic information about the duration effects of freezing temperatures is greatly needed. It would be very useful to study durations that are typically experienced in nature. We know that flowers are generally very sensitive, but it is not known how cold and freezing temperatures affect the functioning of specific parts of the flower.

Infrared Video Thermography

This past fall we performed some experiments using infrared video thermography at the controlled environment facility at UW-Madison, called the Biotron, **to investigate and "see" how ice forms and spreads in fruiting cranberry uprights. This** work was done with the help of Dr. Michael Wisniewski from the USDA Appalachian Fruit Research Station in Kearneysville, West Virginia.

Thermography is a technique for detecting and measuring the heat emitted by objects. Heat waves are detected by a sensor where they are transformed into visible signals that can be recorded photographically, in this case by video. "Infrared" simply describes the type of heat waves, or radiation, that are sensed by the equipment. This technique, then, can visually depict a freezing event since heat is released when water changes from a liquid to a solid.

Uprights with fruits at the blush to red stages of ripening, as well as some detached fruits, were used. Samples were nucleated at 30 or 28°F with a solution containing a protein-producing bacteria to ensure the uniform ice formation on the samples. Following nucleation, samples were cooled to 21°F in approximately one hour. The following observations were made: 1) When nucleated at a cut end, ice propagated rapidly throughout the stem and into the leaves at a tissue temperature of about 25°F. However, ice did not propagate from the stem through the pedicel to reach the fruit. During the one hour after ice propagation in the stem, the fruit remained supercooled. 2) Within the duration of the experiment, leaves could not be nucleated from the upper surface. Ice from the lower leaf surface did nucleate the leaf, and ice propagated from the leaf to the stem and other leaves readily. 3) Both red and blush berries could only be nucleated at the calyx end of the fruit. 4) Red berries supercooled to colder temperatures and for longer durations than the blush berries.

These observations suggest that: 1) **The upper leaf surface and the fruit surface** (other than the calyx end) **are barriers to ice propagation in the cranberry plant;** and 2) At later stages of fruit ripening the pedicel becomes an ice nucleation barrier from the stem to the fruit. This may contribute to the ability of the cranberry fruit to supercool.

Table 1. Cranberry bud development stage terminology and description.

Developmental Stage	Description
1. Tight bud	Resting bud that has fulfilled dormancy requirements. Bud scales are tightly wrapped and the bud has a compact appearance.
2. White bud	Bud is no longer at rest. Bud has begun to swell. Bud scales are pushed outwards and have a slightly loosened appearance.
3. Cabbagehead	Substantial growth of bud has occurred. Bud scales are opening, but new growth is still enclosed.
4. Bud break	Bud growth has taken place. Tips of uppermost new leaves are visible.
5. Bud elongation	Leaves and some flower bracts are visible. All new growth is held tightly and parallel to the stem.
6. Roughneck	Stem has elongated enough to make visible all flower buds and bracts, which are held tight to the stem.
7. Hook	Flower pedicels have elongated such that flower bud droops.
8. Bloom	Flowers open.

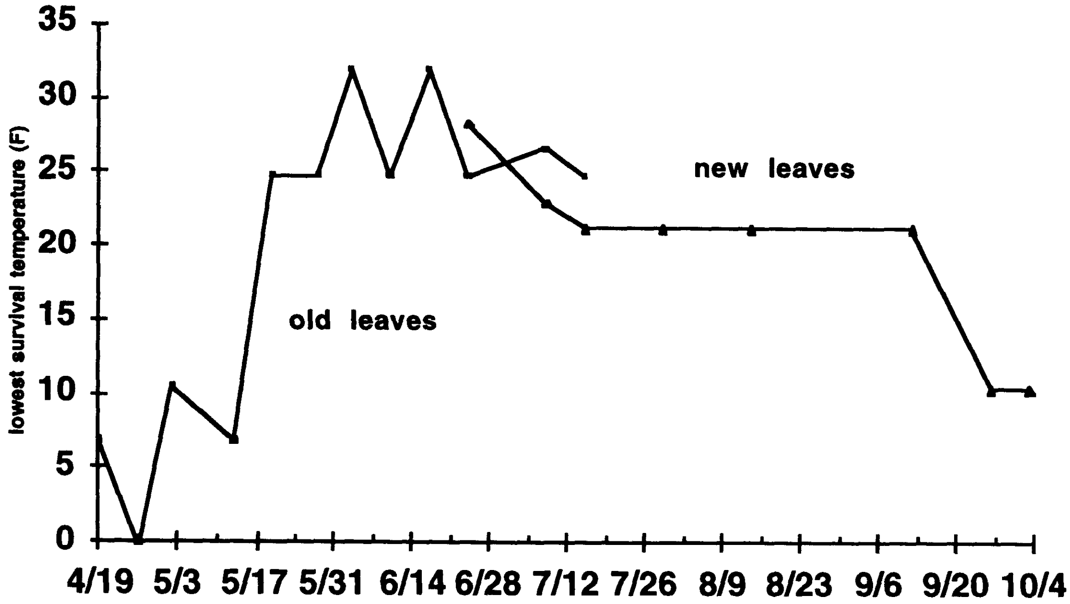

Figure 1. Lowest survival temperatures of old and new leaves from samples collected throughout the 1996 growing season.

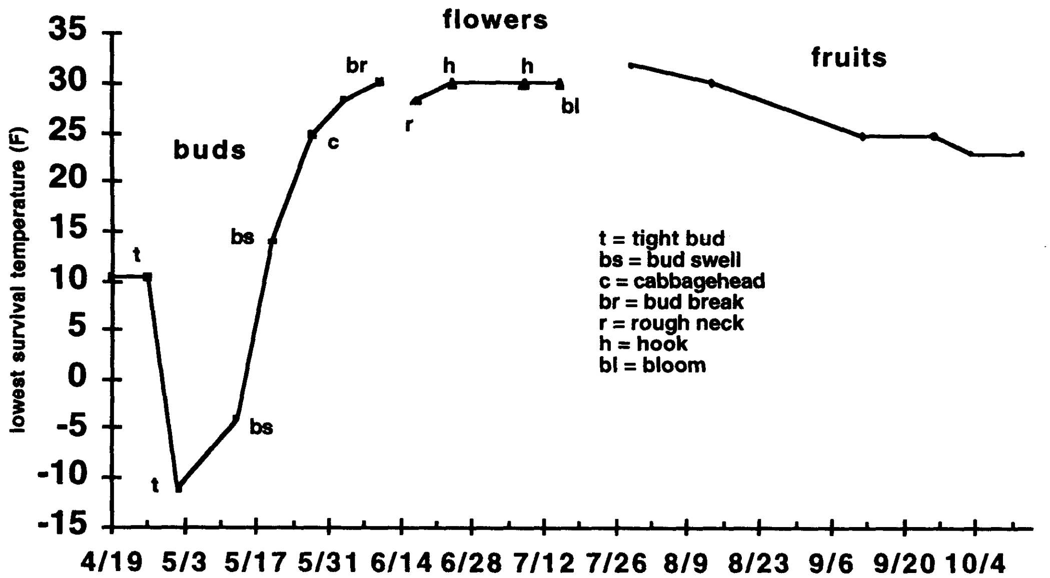

Figure 2. Lowest survival temperatures of terminal buds, flowers, and fruits from samples collected throughout the 1996 growing season.

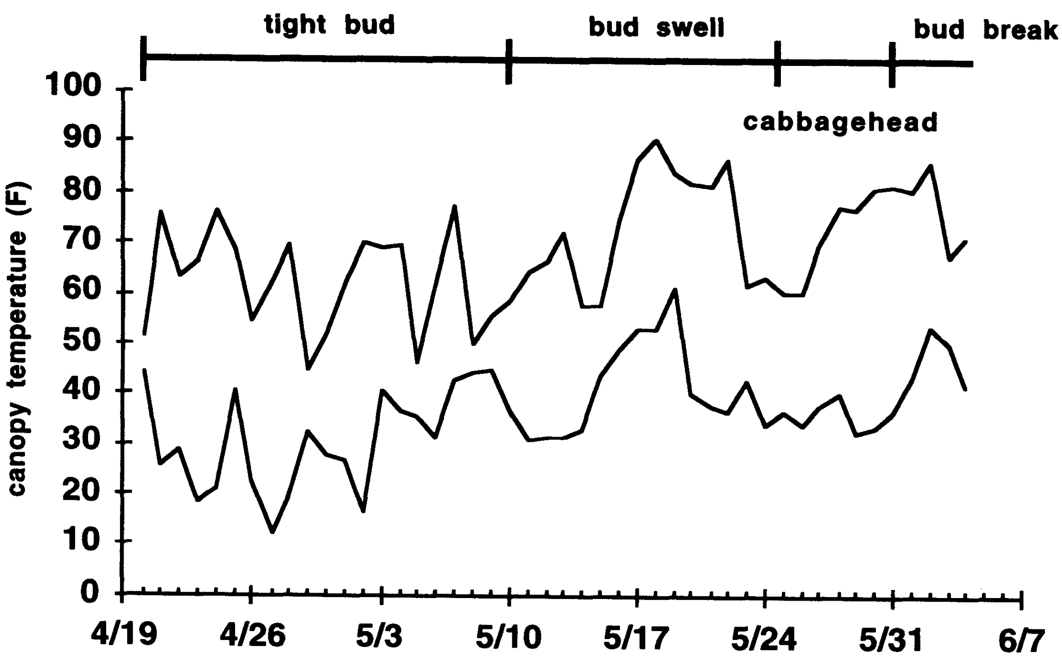

Figure 3. Daily maximum and minimum canopy temperatures recorded at sampling site (near Nekoosa) in Spring 1996.