FALL TO WINTER CRANBERRY PLANT HARDINESS

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Protection of cranberry plants from frost and freezing temperatures is a concern throughout the year. With fall and the transition to winter, protection is necessary for two reasons. Fruit are increasingly vulnerable to frost damage in the period leading up to harvest. After harvest, the only means of protecting the vines is by reflooding, a process that involves the commitment of both labor and water. Learning more about the hardiness of different plant parts at this time of year will help growers to make better decisions on how and when to protect for frost and freezing temperatures. We have investigated several aspects of fall to winter hardiness, including: studying how the plant gets damaged by ice; the lowest survival temperatures for different plant parts; how the hardiness varies with environmental condtions; and the effect of duration of freezing temperatures. All of our recent experiments utilized 'Stevens' plant material collected in central Wisconsin, unless otherwise noted.

How Cranberry Fruit Freeze

The mechanism by which fruit are injured and the degree to which they are able to survive was studied by two methods: infrared thermography and controlled freezing tests. The use of infrared thermography operates on the principles that all objects give off heat (long wave or infrared radiation), and that the freezing of water releases heat (an exothermic reaction). Changes in the temperatures of objects are detected and visualized on a monitoring system. This way the location and spread of ice formation can be observed. Controlled freezing tests are a way to precisely define a plant tissue's hardiness level. In addition, observations about the patterns of damage can be made.

Symptoms of injury in a freeze-damaged cranberry fruit include: a watersoaked appearance (including the bleeding of color from the skin into the fruit's flesh); browning; and the collapse of the tissue. A consistent pattern of damage has been observed in fruit. **Watersoaking and browning are first seen at the the flower end of the fruit.** The injury starts right at the end of the fruit, and then advances like a wave or a front up the fruit until the entire fruit is watersoaked and the integrity of the flesh has collapsed. The same pattern was seen in infrared thermography experiments; the first signs of freezing in fruit consistently occurred at the flower end of the fruit. In general, the amount of watersoaking and damage corresponded to the amount of freezing that had been witnessed on the infrared monitor. However, in several instances where the fruit had just begun to freeze, those fruit showed no signs of freezing damage after thawing. The fact that these fruit appear to recover suggests that **fruit are able to at least tolerate the presence of small amounts of ice in their tissues.**

Stomata have been documented on a portion of the flower end of the fruit, called the nectary (a gland-like structure from which nectar is secreted) (Figure 2). Stomata are pores most found on leaves. Water vapor is lost and gases are exchanged through these pores. **Stomata are thought to be the primary point of entry for ice into both cranberry leaves and fruit** (Workmaster et al., 1999). However, it takes time for the ice to access the flower end of the fruit, since these pores are small.

At the other end of the fruit, it does not appear that ice is able to reach mature fruit by spreading down the pedicel (fruit stalk) from the stem. In infrared thermography pictures, **ice was never observed to spread along the pedicel from the stem to the fruit, after the rest of the upright had frozen.**

Since access is restricted at both ends of the fruit, it is most likely that **fruit survive freezing temperatures by the mechanism of supercooling.** Supercooling occurs when water is able to remain liquid at temperatures significantly below the normal freezing point of water (32F). Other factors also contribute to the ability of the fruit to supercool. The development of a thick cuticle creates a barrier to ice penetration on the fruit surface (Abdallah, 1989). Also, as fruit ripen and increase in sugars and other substances, the freezing point of the water in the tissue decreases. However, at least one study (Abdallah, 1989) has shown that the amount of solutes in the cells of mature, ripened fruit is not great enough to lower the freezing point to the temperatures at which these fruit can survive.

Hardiness Levels of Cranberry Fruit

Our program has evaluated the hardiness of cranberry fruit at different stages of ripeness. Controlled freezing tests have been performed using both fruit attached to the upright, as well as dettached fruit. The lowest survival temperature (LST) (temperature at which no damage is observed) has been determined for stages of fruit development and ripeness from just after fruit set to when fruit are greater than 75% red (Table 1). These hardiness levels are not as low as those listed for comparable fruit categories in the "Frost Protection Guide for Massachusetts Cranberry Production" (DeMoranville, 1998). This may be due to differences in evaluation method and/or growing conditions.

Full size green fruit have an LST of 26.6F (-3C), as do the later stages of riping. However, **at a given temperature, a much higher percentage of green and less red fruit are injured than are the most ripe fruits** (Figures 3). For example, in one set of experiments, at 21.2F (-6C) 25-50% red fruit had around 80 to 90% damage while fruit >75% red had only about 20 to 25% damage. There was no clear pattern in the differences in injury to attached and detached fruit (Figures 3), making it difficult to discern if attached fruit are injured by ice penetrating the fruit from the pedicel.

The duration of freezing temperatures to which fruit might be exposed is an important concern. A series of experiments investigating the effects of freezing temperature and time on the survival of 25-50% red and >75% red fruit showed that the **more ripe fruit were able to survive freezing temperatures for longer durations than were the less ripe fruit** (Figures 4). At 26.6F (-3C), slight damage (less than 5%) occurred in less ripe fruit after one hour, while the more ripe fruit did not show comparable damage. Similarly, less ripe fruit had damage levels of around 60% after two and three hours at 23F (-5C), although the more ripe fruit showed damage levels of only around 20%. The vast majority of fruit can survive slightly freezing temperatures for at least several hours.

Buds

Up to harvest fruit dictate the degree and timing of frost protection. Other plant parts, notably buds and leaves, are of concern after harvest. Cranberry plants, like other woody species, begin the preparation for winter conditions well before harvest, in late summer and early fall. Both the acclimation to cooler temperatures and the onset of dormancy contribute to lower plant hardiness levels in fall. These phenomena are in response to shorter days and colder temperatures. Previous testing of cranberry plant cold hardiness levels in fall (Abdallah, 1989) documented a transition to maximum hardiness levels of both buds and leaves from early September to mid-October, with maximum hardiness being reached by late October.

Our current studies (from 1996,1997, and 1999) confirm the length of this transitional period and the timing of the achievement of maximum hardiness. In 1996 and 1997, upright samples were submitted to a controlled freeze, and then grown in the greenhouse after addtitional chilling was given to the cuttings. The vigor and survival of the new growth was evaluated and a LST was determined. **In both years maximum hardiness was attained for both buds and leaves by the last week of October to the first week of November, with a transition from between 5 to 10F (-15 to –12C) in early September to at least –13F (-25C) by the time of maximum hardiness** (Figure 5). In 1996, a notable loss of hardiness was documented in uprights sampled the week following harvest. This result suggests that **vines may be stressed by either the flooded conditions (low oxygen levels, warmer temperatures relative to the air), or mechanical damage from harvesters.**

In 1999, upright samples of both ‘Stevens’ and ‘Ben Lear’ were evaluated for symptoms of damage one week after being subjected to controlled freezes. Buds were dissected longitudinally and evaluated. ‘Ben Lear’ buds appeared to increase in hardiness earlier than ‘Stevens’ buds, although the buds of both cultivars reached their maximum hardiness by the same time, in late November. There appeared to be no major differences in the transitional hardiness levels of ‘Stevens’ and ‘Ben Lear’ leaves. In late November, it is not known why ‘Ben Lear’ leaves were somewhat lower in hardiness than ‘Stevens’ leaves. ‘Stevens’ leaves reached a maximum hardiness of around –22F (-30C) by late November. Buds and leaves in 1999 appeared to reach maximum hardiness later in the calendar year than in either 1996 or 1997. This could be due to the fact that relatively warm temperatures persisted longer into the fall in 1999 (Figure 7). In 1996 and 1997 the daily average canopy temperature reached 32F (0C) or below consistently by early November, while in 1999, this did not occur until early December.

Conclusion

It is important to consider the hardiness level of different parts of the cranberry plant in order to make the best plant protection decisions. Full-size fruit have been found to survive temperatures down to 26.6F (-3C), although ripe fruit are noticeably hardier than unripe fruit. In addition, ripe fruit can survive 26.6F (-3C) for several hours. Buds and leaves experience a marked transition in their hardiness levels from early September (around 10F (-12C)) to late October/early November (maximum around –13F (-25C) for buds. Harvest activities may affect vine hardiness.

Stage of Fruit Development/Ripeness	Lowest Survival Temperature
Green (<0.5”)	32 F (0 C)
Green (>0.5 up to full size)	30.2 F (-1 C)
Green (full size)	26.6 F (-3 C)
<25% red	26.6 F (-3 C)
25 – 50% red	26.6 F (-3 C)
>75% red	26.6 F (-3 C)

Table 1. Lowest survival temperatures of cranberry fruit at different stages of development and ripeness. ‘Stevens’ cultivar was used for all testing.

Figure 1. Pattern of freezing injury typically found in cranberry fruit. Top row: unijured control. Middle row: small areas of watersoaking and browning are visible only at the flower end of the fruit. Bottom row: “Wave” of freezing continues across fruit from the flower end, until fruit is completely watersoaked and soft.

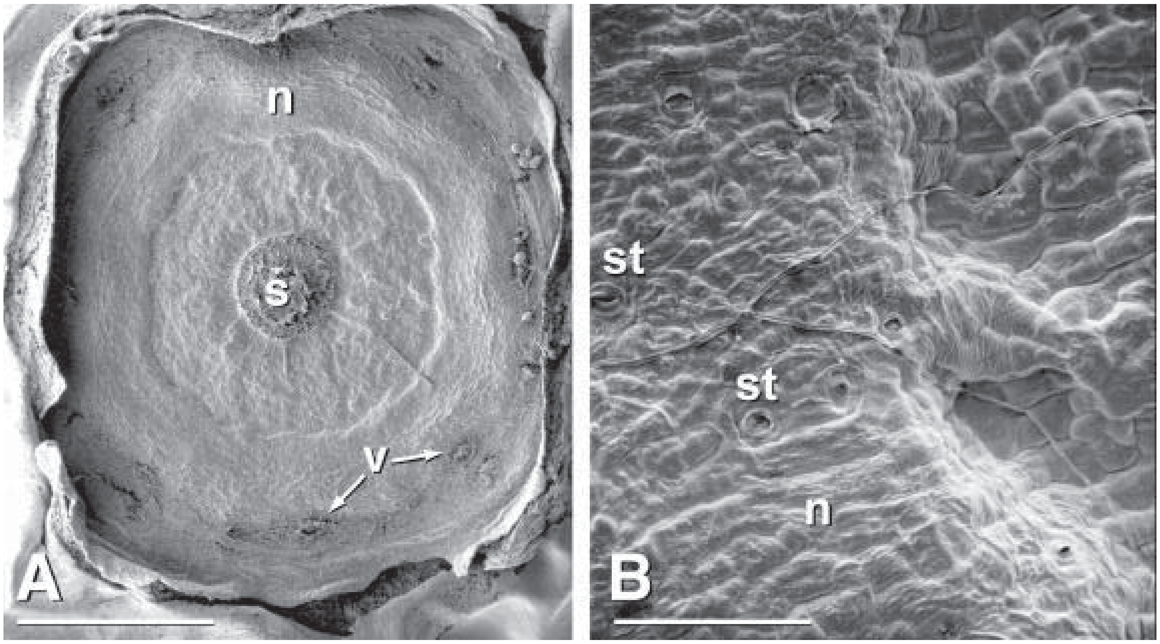
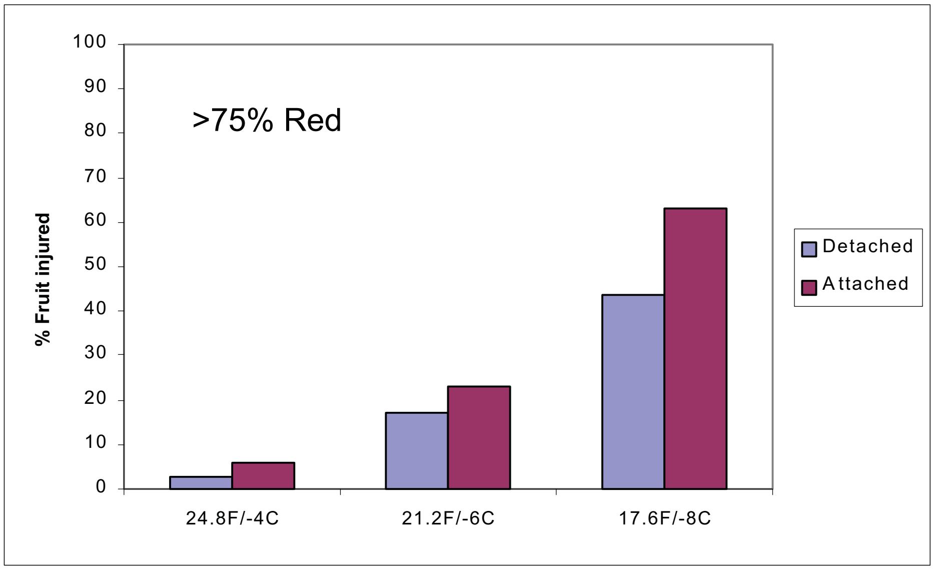


Figure 2. Scanning electron micrographs of the flower end of the cranberry fruit showing the location of stomata. (**A**) Overview of the area (remnant calyx tissue was removed to permit view of fruit end): area of stigma attachment (s), remnant of nectary (n), vascular bundles to stamens and petals (v). Bar represents 0.75 micrometers (ca. 0.03 inches). (**B**) Remnant area of the nectary (n) contains stomata (st), while the area between the nectary and the stigma attachment does not. Bar represents 60 micrometers (ca. 0.0024 inches).



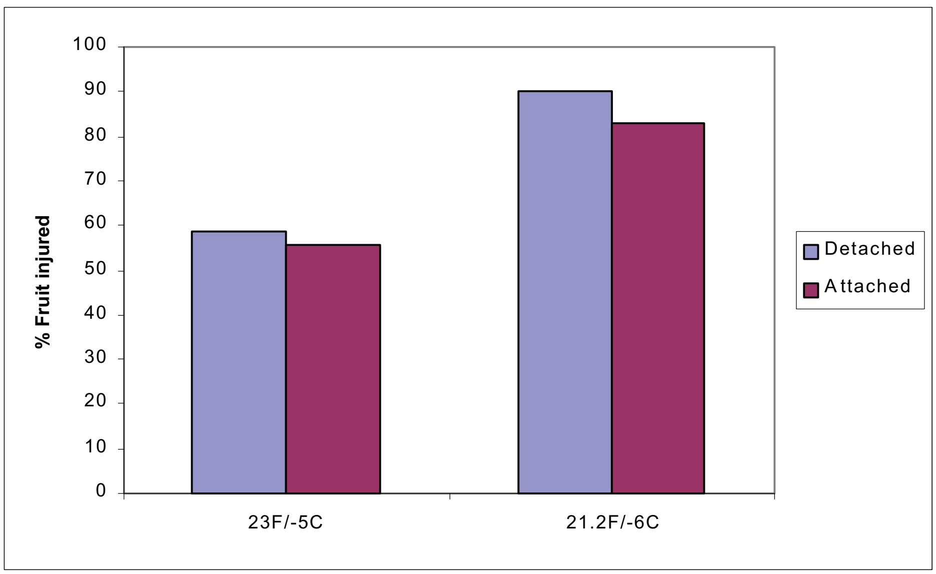
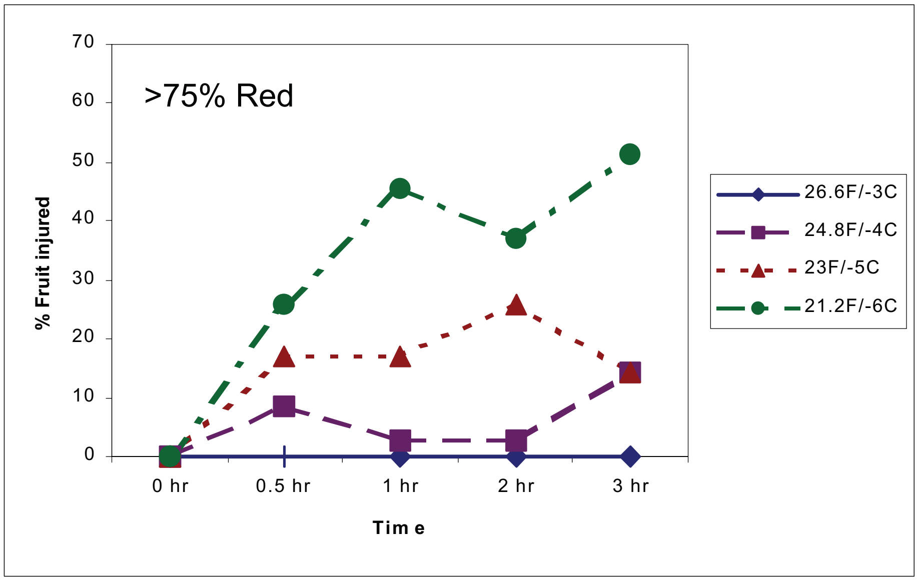


Figure 3. Percent of fruit injured in controlled freezing tests from 1998. Two stages of ripeness were tested (>75% Red and 25-50% Red) in September and October. Detached fruit were excised from upright, while attached fruit retained a portion of the upright stem. Percentages are averages of two experiments (three for 17.6F/-8C) (n=35 fruits for each type in each experiment).



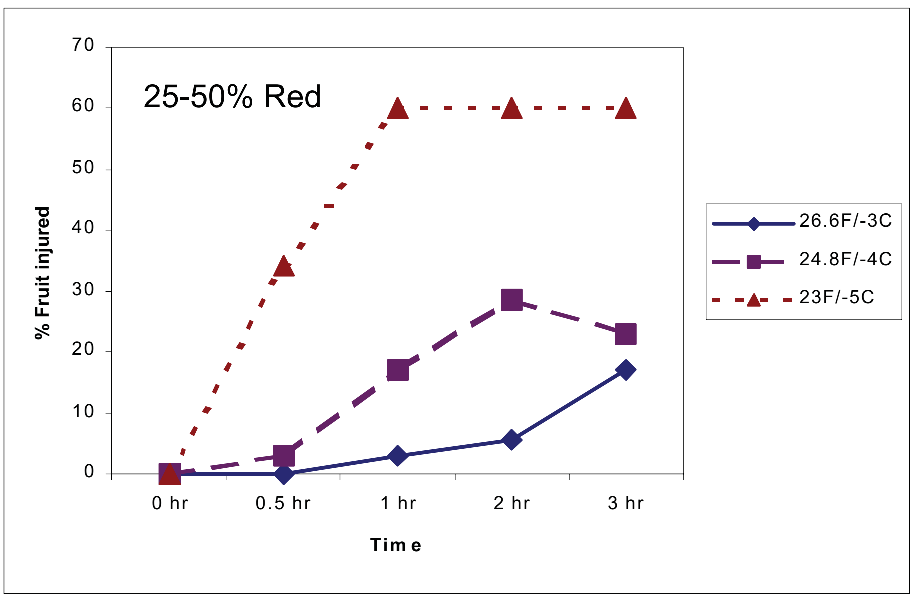
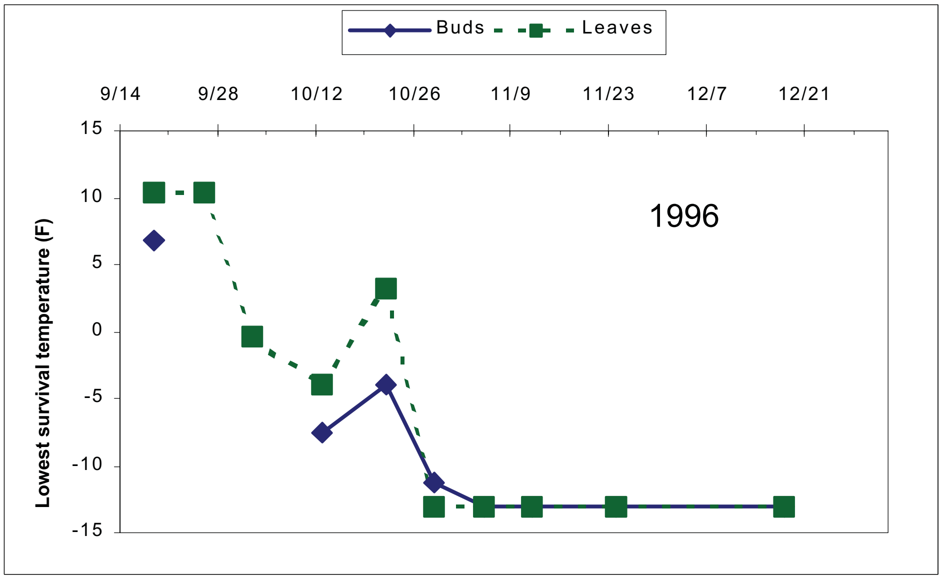


Figure 4. Effect of the duration of freezing temperatures on fruit injury. Individual fruits (n=35) for each duration were cut in half and evaluated for symptoms of watersoaking two days after thawing.



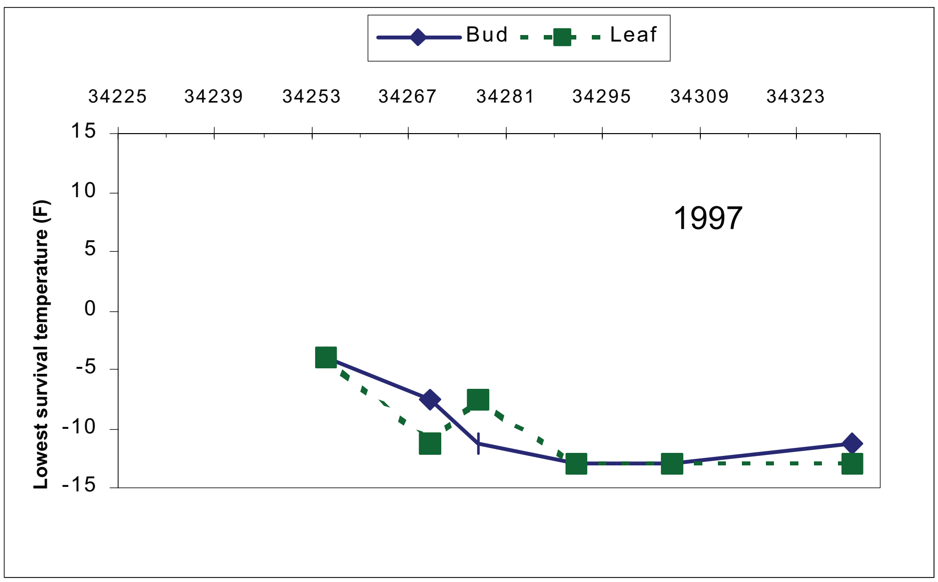


Figure 5. Lowest survival temperatures for buds and leaves of 'Stevens' cultivar in Falls 1996 and 1997. Buds and leaves were evaluated after controlled freeze, additional chilling, and then growth in greenhouse.