Using Ice to Protect Outdoor-Growing Plants against Frosts and Freezes

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In the past few years, I have seen more growers using the outdoors to grow certain container crops that do well in cool environments (Figures 1 and 2). Some cultivars of pansies, petunias, calibrachoas, osteospermums, etc. can be grown outdoors during spring or late spring. Some growers of perennials also move some crops outdoors even earlier in the year.

Figure 1. A large area of outdoor-grown hanging baskets, mainly petunia and calibrachoas. The containers are located on top of a weed matt and irrigated/fertigated with drip irrigation.

Outdoor growing is very tempting because plants can be grown with limited investment: other than the direct cost of crop production, this type of growing requires a weed mat and a simple watering system. However, the big question is: what happens if a frost occurs when the plants are outside? This is a risk that growers are willing to take and they try to minimize the risk by using some preventative measures.

Before we describe one of the tools available to protect crops from frosts, let us define *frost* and *freeze*. For many people, these two words mean the same thing: temperatures below 32°F that cause plant damage. Technically, however, there is an important difference between the two. Frost occurs when the air is dry, the wind is calm, and there is no cloud cover in the sky. The technical name is *radiation frost* because the air near the ground is colder that several feet above. Freeze occurs when a strong cold air mass covers a given geographical area. Winds of at least 5 mph are also part of this type of plant-damaging cold temperature system. The technical name is *advection freeze* and is commonly known as black freeze.

Figure 2. A mature pansy crop grown outdoors on a weed matt. Note the "spaghetti" tube irrigation.

In the case of frosts, growers can cover plants to be protected with some type of thermal blanket. For large areas, the blankets become impractical, in some cases requiring some type of support to avoid plant breakage.

Other growers use instead watering sprinklers for frost or even freeze protection (Figure 3). The sprinklers must be turned on before the temperatures fall below a certain value. The sprinklers must be left on all the time until the temperatures rise. The watering system must be turned off only when the air temperatures are high enough to not produce any plant damage. The water droplets are deposited on the plants. The water droplets freeze and while this water freezing process occurs, it releases heat that protects the plants. It is scary for some growers to see the plants they want to protect being covered by a sheet of ice (Figure 4). How is it possible that by covering the plants with ice we protect them from freezing?

Figure 3. A large outdoor growing area with hanging baskets. Note the spaghetti-tube drip-watering system (arrow) and a sprinkler head (circle) used to spray water during frost periods. (Photo courtesy Matt Foertmeyer)

Let's review some basic high school physics. Figure 5 is a cartoon representing the three possible states of water: solid (ice), liquid, or vapor. Each state has a given level of latent energy, highest for vapor, lowest for ice, and intermediate for liquid. When changing from one state to another, water either requires (has to be given) energy or it releases energy. For example, ice requires heat (energy) to melt. When liquid water becomes ice, it releases heat (energy). It is this heat released by freezing water that it is used to protect the plants.

Figure 4. Hanging basket plants grown outdoors covered by a sheet of ice after a night of being irrigated with a sprinkler frost-protection system. (Photo courtesy Matt Foertmeyer.)

How much heat can be released with this frost protection system? Water applied with sprinklers at a rate of 0.08 inches per hour (36 gal. per min. per acre) releases 2.6 million BTU per acre per hour[1].

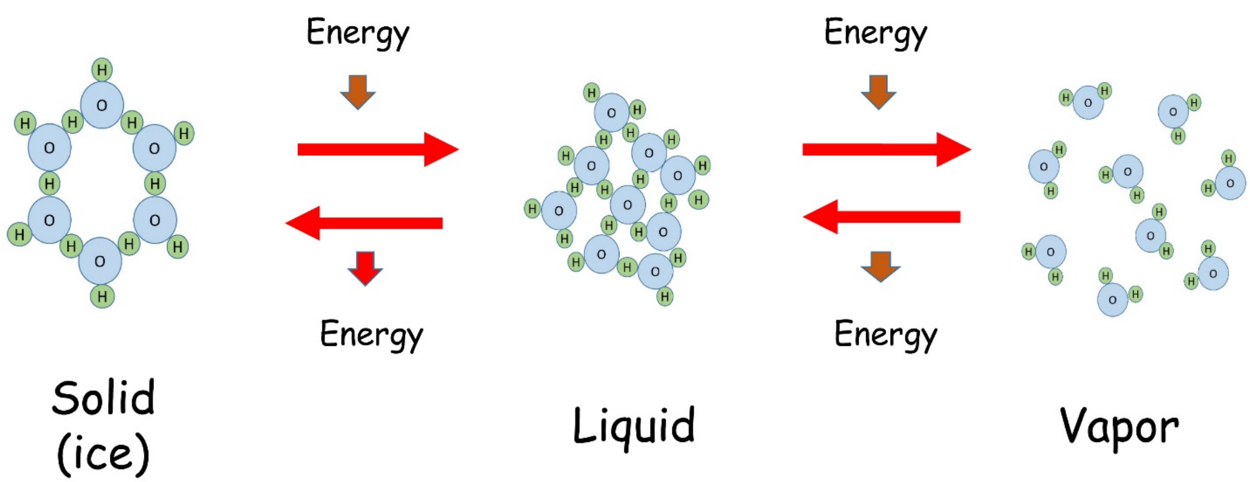

Figure 5. A drawing representing the three states of water. Blue circles with a letter O represent oxygen atoms; smaller, green circles with the letter H represent hydrogen atoms. Note that when liquid water becomes ice, energy (heat) must be released. Water molecules in ice are more separated than when in the liquid stage; that is why ice floats.

Increasing the application rate to 0.15 inches per hour (68 gal. per min. per acre) provides 4.9 million BTU /ac/h. As long we are not dealing with a deep freeze, this amount of energy should be sufficient to protect most crops assuming that the watering system has been well designed.

> It is not the ice surrounding the plant that provides the protection, rather, the constant freezing of water over the surface of the ice.

Some important considerations:

- The area to be protected with the sprinkler system needs to be watered all at once.
- It does not work to divide the area into sections that are turned on and off as is done for irrigation.
- Given that the system has to run all the time when temperatures are at or below freezing, the system has to have the capacity to run for very long times. This includes reliability (no interruptions) and large volumes of water. Some growers mistakenly rely on ponds that do not have the adequate volume of water. If the area to be protected is one acre in size, and the desired rate of delivery is 0.125 inch/acre/hr., 60 gallons of water per minute will be needed which represents 3600 gal/hr[2].
- Use sprinkler heads specifically designed for frost protection. If rotating sprinklers are used, they should rotate at least once a minute.
- The spacing and location of the sprinklers is also important. Consult the sprinkler manufacturer for the proper selection and design.
- The ice formed around the plant should be clear. Cloudy or milky ice is an indication that the water-application rate is insufficient (too low).

When to start the watering system for frost protection purposes

If the dew-point temperature is known, growers should start the watering system when air temperatures have reached the values found in Table 1 below.

Table 1. Suggested starting temperatures for watering, based on dew point.

Dew Point Temperature	**Suggested Starting Temperature[2]**
30.01°F (-1.1°C)	32.00°F (0.0°C)
28.94°F (-1.7°C)	32.90°F (0.5°C)
26.96°F (-2.8°C)	33.98°F (1.1°C)
25.16°F (-3.8°C)	34.88°F (1.6°C)
24.80°F (-4.4°C)	36.86°F (2.7°C)
22.10°F (-5.5°C)	37.94°F (3.3°C)
10.94°F (-6.7°C)	38.84°F (3.8°C)
17.06°F (-8.3°C)	39.92°F (4.4°C)

Another way of deciding when to start the sprinklers requires the use of wet bulb temperature. When the wet bulb temperature has reached the temperature that will produce crop damage, the frost protection system should be turned on.

When to stop the watering system for frost protection purposes

The system should be turned off only when the temperatures rise to or above temperatures that cause damage. Even though the sun may come out and start melting the ice, the temperature can still remain dangerously low. Having an infrared thermometer to directly measure plant tissue temperature can be very useful. If the temperatures do not rise above freezing for days, the sprinklers will have to be working all that time. Ice accumulation on top of plants can be substantial (Figure 6).

Further considerations

With this frost-protection system, large volumes of water are applied to the crop. As a result (especially when ice melts), nutrients are leached out of the containers. Fertilizers need to be re-applied to restore proper levels of fertility for each crop.

Figure 6. Substantial amount of ice accumulated on top of perennial plants grown in containers outdoors after the sprinklers run for several days during a freeze. (Photo curtesy of George Pealer.)

The high volumes of water applied can also be a problem after melting since the water has to drain to a lower area otherwise the containers will sit in a flooded area creating a sanitary hazard for the plants.

At the time when this frost-protection system is used, some crops may have dense and tall canopies. In such cases, the weight of the ice can cause branch breakage. If the sprinklers produce a mist that surrounds the plants on all sides, the ice may create a structure that supports itself without breaking the plants.

If the sprinkler system is not designed properly, not enough ice will be produced. As a result, not enough energy will be released to protect the plants and the plant will suffer damage. (Figure 7).

Figure 7. Petunia plants showing frost damage caused by a deep freeze even though they were protected by a running sprinkler system. These plants, although damaged, will be sold after a short time of recovery. Without the protection system, these plants would have died. (Photo courtesy Matt Foertmeyer)

A word of caution

If a grower has never used this frost-protection system, it would be prudent to request advice from experienced growers and/or Extension personnel. Start small, initially protect a small crop and only when comfortable expand over time the area to be protected.

[1] www. Irrigation-mart.com
[2] http://www.omafra.gov.on.ca/english/crops/facts/frosprot_straw.htm