Understanding Frost in Fruit Crops

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Low spring temperatures can cause significant damage to fruit crops by damaging the developing fruit buds causing significant economic loss to growers. Managing the risk of frost damage begins before the crop has even been planted by selecting a site that optimizes cold air movement and selecting cultivars that are appropriate for the region. When making decisions about how to protect a crop against frost damage, it is essential to understand the different types of frost and how conditions will influence which protective measure to use.

Determining the Critical Temperature

Before making any decisions, it is essential to know what stage of development the fruit bud is at in order to determine how susceptible the buds are to damage. This will influence the decision of if protection is necessary and if so, at which temperature damage will occur. As the fruit buds develops in the spring, the ***critical temperature – the temperature at which buds and/or other plant tissue can be killed,*** increases as the bud stage advances.

Therefore, the first step in frost protection is determining what bud stage you are at and the critical temperature the buds can tolerate.

Critical temperature table for fruit crops:
http://www.ipm.msu.edu/pdf/fruitfreezeTable.pdf

Tree fruit bud stages:
http://fruit.wisc.edu/wp-content/uploads/2012/03/Tree-Fruit-Development.pdf

Cranberry bud stages:
http://fruit.wisc.edu/wp-content/uploads/2012/03/Cranberry-Development.pdf

Types of Frost:

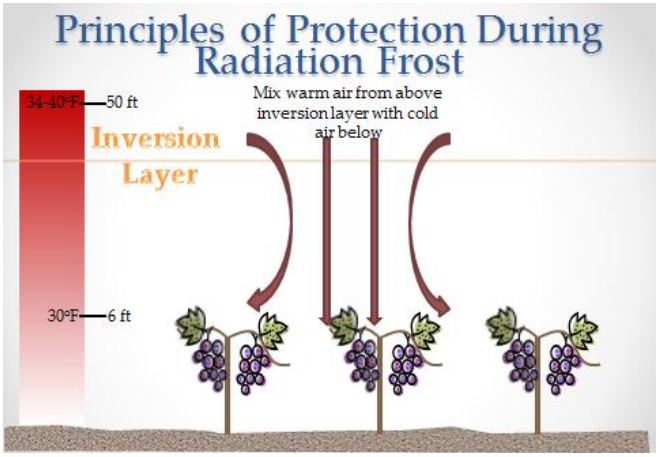

Fig. 1. A radiation frost is characterized by clear calm conditions that allow the development of a temperature inversion layer.

Radiation Frost. Frost typically occurs on a clear, calm night which allows the development of an inversion layer which is characterized by cold air that settles in the bed and becomes warmer until you reach the 'inversion layer' where the temperature gradient is reversed and temperatures get progressively colder as you increase in altitude. The inversion layer is typically around 40-70 feet about the ground. Frost protection with wind turbines or forced air displacement systems are based on the idea of either 'pushing' the warm air

at the inversion layer down or forcing the cold air up. During a frost event, the plant tissue is warmer than the air, so the tissue 'radiates' heat to the surrounding air and will progressively get colder and if air temperatures are colder than the critical temperature, the tissue will be killed.

Advective Frost/Freeze. This type of frost/freeze occurs when a cold air mass moves through an area and is accompanied by strong wind. It is difficult to protect a crop under advective freeze conditions. IRRIGATION OR WIND MACHINES SHOULD NOT BE USED DURING ADVECTIVE FROST/FREEZE EVENTS.

IMPORTANCE OF DEW POINT.

Effect of Dewpoint During Frost Events

Example 1: Air Temp = 35°F, Dewpoint Temp=33°F

- Temperature will drop quickly until it reaches 33°F when condensation will form on the buds.

- Heat of condensation will compensate for some radiative heat loss and slow the rate of cooling

Example 2: Air Temperature =35°F, Dewpoint= 27°F

- Temperature will drop quickly until it reaches 27°F

- Damage to buds can occur quickly, so protective measures must be started earlier

The rate at which the bud temperature drops will be relatively fast until the temperature reaches the ***dew point* – the temperature at which condensation of the water vapor in the air first occurs.** The reason that bud cooling slows down when the dew point is reached is due to the release of heat that occurs when condensation is formed. This heat release compensates for some of the radiative heat loss slowing down the rate of cooling. So why is the dew point so important to watch? If the dew point is below your critical temperature, the buds will reach the critical temperature very quickly, and so protective measures must be accurately timed as damage can occur quickly. Under these conditions the white crystals typically seen during a frost may not form as there is no condensation at the freezing point, this is often referred to as a 'black frost'. If the dew point is above the critical temperature, the buds will approach the critical temperature more slowly so you have some more time to make decisions.

Calibrating Thermometers. Your ability to accurately protect against frost relies on accurate thermometers. It is therefore important to calibrate your thermometers. This is easily done by placing your thermometers in a container of ice water. The temperature should read 32°F, if the thermometer is reading higher or lower, note the 'offset' and write it directly on the thermometer so you can adjust the temperature reading in the field.

PROTECTING AGAINST FROST

Optimize Cold Air Drainage

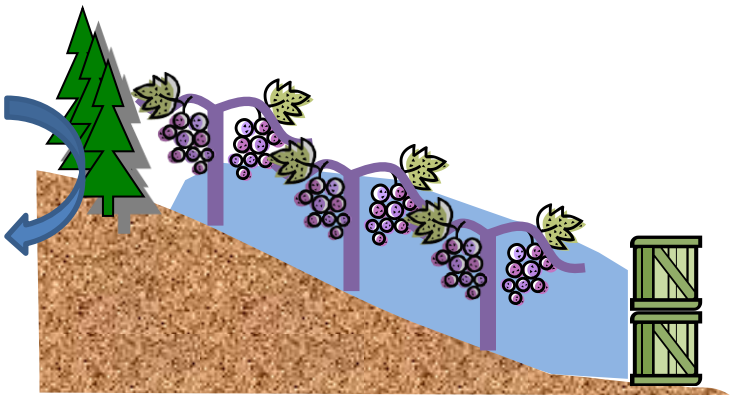

Figure. 2. Clear any cold air drainage path from obstructions to minimize pooling of cold air

The most severe frost damage will occur in areas where the cold air has pooled and therefore exposes the buds to longer periods of exposure. In addition to establishing the fruit planting on a site that has goo air drainage which will allow the cold air to continue to move out of the fruit planting, it is essential to ensure that there are no obstructions that may be preventing the movement of air through the planting. Walk through the vineyard or orchard and look for large piles of brush, stacked crates or any other large objects or dense plantings that may obstruct the movement of cold air and allow pooling.

Double/long cane pruning Grapes

Unpruned vines can be up to two weeks later to break bud compared to pruned vines. The buds will begin to open from the distal end, the basal buds will be delayed as they will not open until all the distal buds have opened. This can be an effective approach to minimizing crop loss due to frost however, there are some challenges. This *double pruning* approach requires a follow-up pruning which is labor intensive and therefore expensive. In addition, cane removal during the follow-up pruning can lead to extensive bud damage as the developed buds can break easily.

Irrigation

Applying water to protect the crop from frost is used in fruit production and is perhaps the most effective method of crop protection, though it is expensive. The principle of protecting the crop through irrigation is based on the *latent heat of fusion – the heat released during the transformation of liquid water to ice.* The transformation of one gallon of liquid water at 32^{o}F to ice at 32^{o}F releases 1200 BTU of heat. It is the release of this heat that maintains the plant tissue at 32^{o}F and prevents the tissue from freezing. Colder temperatures will require more water in order to provide enough heat to protect the crop.

When to Start Irrigating. The general recommendation for fruit crops is to start the system when the temperature is 4^{o}F above the critical temperature. When the irrigation is turned on, the application of water on the plant tissue causes a short term 'dip' in tissue temperature due to evaporative cooling (the

same principle used to cool the crop during hot days). Therefore, it is critical to turn the irrigation on before you reach the critical temperature to ensure that the 'dip' caused by evaporative cooling does not result in the tissue temperature going below the critical temperature. A 'wet bulb' temperature can be a better indicator than the 'dry bulb' (standard thermometer) temperature of when the irrigation should be turned on.

Wind Machines

During radiation frost events (calm, clear nights) the air layers with the cold air near the ground forming what is called a temperature inversion. Wind machines and helicopters can be used to 'mix' the air and bring the warm air down from the top of the inversion down to replace the cold air at crop level.

There are several types of wind machines: tall fans that "push" the warm air down, air displacement systems that force the cold air up which results in the draw down of warm air. DO NOT USE WIND MACHINES DURING ADVECTIVE FREEZE AS THIS WILL INCREASE DAMAGE.

Heat

Heat can be added to the vineyard by driving around with a mounted heater like the 'Heat Dragon' or multiple small fires around the vineyard. This can be an effective means to increase the temperature of the vineyard. The challenge with this approach is time and labor. If using a mounted heating device, you must be sure that you will have time to cover the area. If lighting fires, you must be sure to not light a big fire as it can cause a break in the inversion layer and draw in cold air. Therefore, it is a challenge to continuously monitor small fires.

Row Cover

Spunbonded fabrics (polyester or polypropylene) row covers can be used to protect fruit crops. Row covers must be applied before sundown to ensure heat is not lost. Rowcovers can increase temperatures by 2-4^{o}F but have limited ability to protect a crop when temperatures are below 28^{o}F. Plastic covers should be used with metallic hoops to ensure the plastic is not in contact with sensitive flowers and damage can occur. Row covers can be effective during an advective freeze or radiation frost.

Oils (Grapes)

There has been some work showing that use of oils can delay bud break with winter and spring applications. Work done by Dami and Wolf (**http://dc380.4shared.com/doc/4sw2oQtu/preview.html**, accessed March 23, 2012) showed that soybean oil (i.e. Amigo) could delay budbreak (JMS stylet oil was more toxic) when applied in winter or early spring. It is doubtful that this would be useful if applied now when we are already in or very close to bud break.