Strawberry Plasticulure Advisory on Cold Protection

Vol. 6 No. 11

Barclay Poling (April 15, 2005)

Cold protection in the early bloom period

Row covers are usually the safest method of cold protection early in the season. The emerged flower bud/early blossom stages typically occurs in the Mid-South, from the end of February through early March. Unfortunately, at this time in late winter, the entire region is subject to advective, or windborne *freezes* (see Types of Cold Events). Windborne freezes can cause devastating crop losses and significant delays in the start of the harvest season (1 to 2-weeks). Under *freeze* conditions, overhead sprinkler irrigation is very risky due to a phenomenon known as *evaporative cooling.* Strawberry plants are most effectively protected at the early blossom/emerged flower bud stage in the season with floating row covers of medium to heavy weight (0.9 or 1.0 oz to 1.5 oz per sq yd). Row covers of medium weight (1 oz) can provide several degrees of cold protection, and this is usually adequate to keep emerged flower buds above their critical temperature of 22^{o} F, when "outside" temperatures are in the upper teens (Table 3). Losses of the earliest open blossoms (critical temperature of $30\,^{o}$F), will not be prevented with row covers when temperatures are in the low 20s and upper teens. However, this loss of the first 3 to 4 blossoms per plant with Chandler and Camarosa, is of little economic consequence as these flowers typically develop into berries that are poorly shaped, and have little market acceptance.

<u>Types of Cold Events</u>.

- A *freeze* is defined by the National Weather Service (NWS) as having wind speeds of more than 10 MPH and air temperature of below 32^{o}F
- A *frost/freeze* is defined by the (NWS) as having wind speeds of less than 10 MPH and air temperature of below 32 F.
- As defined by the NWS, a *frost* has wind speeds below 10 MPH and air temperature above 32 F.
- A *hoar frost,* or white frost, results when atmospheric moisture freezes in small crystals on solid surfaces.
- A *black frost* is one in which few or no ice crystals form on the plant because the air in the lower atmosphere is too dry.

Table 3. Critical temperatures of strawberries based on stage of development.

Stage of Development	Approximate Critical Temp. (^{o}F)
Tight bud	22.0
"Popcorn"	26.5

Open blossom	30.0
Fruit	28.0

Source: Perry and Poling (1985)

Main blossom period (weeks 4 – 8)

The main blossoming period *starts* approximately 4 to 5-weeks after the beginning of new leaf growth in late winter, and continues for about one month. This is generally the most complex period in the crop cycle for the protection of blossoms various pathogens and cold injury. The most common and serious disease of strawberry fruit at this stage is Gray Mold, also referred to as “Botrytis”. The pathogen attacks the blossoms when conditions are favorable. Overhead irrigation for frost/freeze management during bloom can cause conditions favorable for botrytis infection, as will cool wet weather. You will need to consult local recommendations in Illinois for fungicides that are effective for managing gray mold fruit losses if applied during bloom. If plants are infected with anthracnose, it will be control to undertake a control program with a **strobulurin** based fungicide beginning at bloom.

Cold events during bloom. A variety of different types of cold events that can occur at this stage, that can still include windborne freezes, but the majority of cold events are *frost/freezes* (see Types of Cold Events). During the bloom period, growers need to also be on alert for conditions that favor *frost* formation at the ground level. Even when dew point temperatures and air temperatures are forecast to be in the upper 30’s at the weather shelter height (5 ft), it is still possible to have a killing frost at the strawberry canopy level. Overhead sprinkler irrigation is the most effective method for *frost/freeze* and *frost* protection of the popcorn and open blossom strawberry flower stages. Table 4 provides an important overview of the *relative* effectiveness of various protection methods for each type of cold event you may can encounter during bloom. Row covers are inconvenient to use during the bloom period because as they must be pulled back each morning following a night of cold protection (for bee and insect pollination), and a medium weight row cover (1 oz) is not reliable for more than 3 to 4 degrees of cold protection.

Table 4. Protection Effectiveness by Cold Event Type, Flower Stage and Control Method (Rating scale: 4=excellent; 3=good; 2=fair; 1=poor)

Type event	Flower stage	Rover Cover (alone)	Sprinkling (alone)
Windborne freeze	Emerged fb[1]	3-4[2]	not recommended
Windborne freeze	Open blossom	2	not recommended
Frost/freeze	Emerged fb	4	4

	Open blossom	2	4
Frost	Open blossom	3	4
	Popcorn	3	4

[1] fb = flower bud; [2] the "protection effectiveness" of row covers alone will depend on cover weight, min. temperature, and humidity

Weather forecasts. A good cold protection strategy requires a reliable weather forecast for your farm that is delivered in timely way and should include information on:

- When the cold event(s) is (are) coming?
- How cold it will get (minimum air temperature at the canopy level)?
- How long the cold may last (duration)?
- Wind speeds and direction?
- Humidity – will it be low, or high? (dew point is one of the better ways to describe the amount of water vapor in the air)

You can organize a journal that includes information relevant to formulating a successful cold protection strategy:

- Date of cold event: __________ Type of event: ________________________ (freeze, frost/freeze, frost)
- Minimum dry bulb temperature (5 ft): __________ Minimum dry bulb temperature (canopy): ___________
- Wind speeds: ___________ Directions:_____________ Cloud cover:_________________
- Dewpoint temperature (frost point): ___________

You can record information for each cold on both *anticipated* and *actual* temperatures, wind speeds, and irrigation rates. It is also helpful to note start-up and shutdown times, and the crop outcome. A suggested format is provided below:

- Forecasted minimum temperature: __________ (5 ft) ____________ (plant canopy)
- Actual minimum temperature recorded: __________ (5 ft) ____________ (plant canopy)
- Forecasted wind speeds: __________ (early evening) _________ (midnight) __________ (early morning)
- Actual wind speeds: __________ (high) ___________ (low) _____________ (average)
- Anticipated precipitation rate (inch/hr): _______________ (calculated from Table 5)
- Actual precipitation rate used (inch/hr): _______________ Special notes: ________________________

- Anticipated start-up *time* for very low dew point (teens, lower 20s): ________
- Anticipated start-up *time* for low dew point (mid-20s) _______
- Anticipated start-up *time* for dew point hovering around or below 30 F ______
- Actual start-up time: ________ air temperature (dry bulb):________ blossom temperature: _______ (if available)
- Hour in evening when wet bulb temperature should drop to 32 F ______ 30 F _______ (strongly recommended)
- Hour in morning when wet bulb temperature should return to 32 F ______ 30 F _______ (strongly recommended)
- Actual shutdown time: _________
- Actual blossom temperatures at shutdown in morning _________ (if available)
- Assessment of blossom condition in later morning (~11 am): ____

How do I get the most accurate forecasts? Commercial providers of specialized weather forecasts are increasing, and a number of these services are web-based and offer a variety of products, including in-depth forecasts for larger cities like Raleigh, NC, and then have more limited forecasts for smaller towns (mainly maximum and minimum temperatures). Other services are more farm-specific, and will provide twice daily reports via email and fax. All of these services provide 7-day forecast of maximum and minimum air temperature, 24-hour forecasts of hourly minimum temperatures that are updated twice each day, and should offer information on dew point and/or wet bulb temperature, as well as variety of other products, including wind speeds. If you do not subscribe to a service, and wish to have wet bulb information, a sling psychrometer is a device that you can use to determine wet and dry bulb temperatures.

AWIS Inc. – Agricultural Weather Information Service, PO Box 3267, Auburn, AL 36831-3267 (334-826-2149) www.awis.com

SkyBit, Inc., PO Box 10, Boalsburg, PA 16827-0010 (800-466-6691), email: eweather@meso.com

Thermocouple temperature measuring unit for blossoms. Events can change quickly during the day leading up to a frost/freeze (e.g. cloud cover can move in), and on the eve of sprinkling for frost/freeze, forecasted conditions may not match what is actually happening in your field and at the plant canopy level. One of the simplest and most reliable methods for monitoring the "net effect" of changes in air temperature, humidity and wind speed, is to check the *actual temperature of the blossom* with thermocouple temperature measuring devices that are small enough to be inserted into buds or blossoms. Thermocouple blossom temperature are reliable for guiding decisions on: 1) when to start irrigation, 2) whether irrigation is sufficient (if blossom temperatures drop below 30^{o}F, sprinkling rate must increase), and 3) they remove the guesswork associated with the decision as to when it is safe to turn off the irrigation system in the morning, which is a very difficult decision to make on some occasions, especially when dew point temperatures are very low and winds pick up in early morning. As you become familiar with the use of thermocouples to monitor strawberry blossom temperatures, you will notice that blossom temperatures are frequently 1 to 2 degrees F below the canopy air temperature as measured with a liquid-in-glass thermometer (i.e. when blossom temperature is reading 31^{o}F, the air temperature in the plant canopy may be 32 or 33^{o}F). Please contact your County Extension Center for current details on purchasing a unit for blossom temperature measurement.

Regardless of instrument used for temperature measurement, it must be calibrated. This means the instruments must be checked, and adjusted if necessary, to ensure they are reading temperatures correctly. A simple way to make sure the device is reading correctly is to place the sensor into water with crushed ice, gently stirred. Make sure the sensor or thermometer base is submerged in the water, The temperature should read within one degree of 32^{o}F in 10 to 15 minutes.

When sprinkler irrigation may *not* be a good option – begin with an evaluation of crop stage!

Evaluating crop stage, protection options, and economic benefits of protection. Know your crop! Prior to the cold event, closely inspect plants in the field by pushing back foliage and examining the emerged flower buds, popcorn blossom stage flowers, and open blossoms. A careful evaluation of crop stage early in the season may indicate that overhead sprinkler irrigation is not the best option.

- *Crop stage* - from 20 plants randomly sampled, calculate these averages:
    - Ave. number of emerged flower buds (critical temp. 22^{o}F)/plant: __________
    - Ave. number of popcorn stage blossoms (26.5^{o}F)/plant: __________
    - Ave. number of open blossoms (30^{o}F)/plant: ________

Protection options for emerged flower buds in freeze conditions. Next, considering the average critical temperature for each of these stages, make an estimate of the potential economic losses that could be associated with the forecasted cold event if no protective action is taken. For example, if a windborne freeze with minimum temperature 19^{o}F is in the forecast in late February (Mid-South), there is an excellent chance that all of the emerged flower buds and open blossoms will be killed. If your field inspection indicates an average of 6 emerged flower buds per plant, but just a few open blossoms, the most sensible strategy may be to simply apply row covers prior to the freeze, and not attempt sprinkling. The 1 oz/sq yd row cover should provide several degrees of protection, thus keeping the flower buds alive (19^{o}F minimum temperature + 3 F protection = 22^{o}F under the row cover). Greater protection can be expected with a heavier row cover of 1.5 oz/sq yd.

Economic value of row covers. As far as placing an economic value on saving 6 flower buds per plant, you may wish to consider that 6 early season berries of Chandler will weigh about ¼ lb (about 20 grams each). Thus, if you have 15,000 plants/acre, the loss of 6 flower buds per plant could represent 3,750 lb/acre x ave. price/lb. If you sell U-pick berries for $1.00/lb, the loss of these first flower buds will approach $3,750, which far exceeds the cost of a 1 oz/sq yd row cover (usually around $900/acre). In this particular scenario, the grower would achieve more than a fourfold payback in terms of the value of the crop saved vs. the cost of the row cover ($3,750/900=4.2).

Risks associated with sprinkling in windborne freeze conditions. With windborne freezes in the early season, you are almost ways better off using row covers alone when you are mainly concerned about protecting the flower buds, and do not wish to risk more extensive crop losses to evaporative cooling effects if sprinkling is inadequate, or the irrigation system fails during the night.

Using Sprinkler Irrigation for Frost/freeze and Frost Control

Understanding 2 key principles – 'heat of fusion' and 'heat of vaporization.' The basic principle behind sprinkling for frost and frost/freeze protection is that as water freezes, heat is released by the freezing process (heat of fusion). The amount of heat generated when water freezes is 1200 BTUs/gallon or 80 calories/gram of water frozen. This heat keeps plant temperatures at 32 F, even when air temperatures are colder. As long as an *adequate layer of freezing water* covers the blossom, the temperature will stay above the critical damaging temperature for an open blossom (30 F). With very low air temperatures, higher rates of water application are required for adequate protection. Evaporative cooling (heat of vaporization) is the heat loss when water changes from a liquid to water vapor. At 32 F, the heat of vaporization is about 8,950 BTUs/gallon or 596 calories/gram of water evaporated. Note that this process is about 7 ½ times greater than the heat of fusion. This means to maintain a stable situation when both freezing and evaporation occur, for every gallon of water that evaporates, 7 ½ gallons of water need to be frozen to balance out the heat in the field. If the irrigation rate is not adequate, greater damage to the crop can result than if no protection had been provided!

Step-by-step Frost/freeze Protection with Medium to High Winds

Our experience has shown that is possible to successfully irrigate to protect strawberry blossoms and buds in medium (5-8 MPH) to high winds (9-14 MPH), using sprinkler irrigation application rates that are derived from Table 5. In addition to monitoring forecasted minimum temperatures and wind speeds, *you must also watch wet bulb temperatures in using water to protect under windy conditions.*

Table 5. Required irrigation rates, in/hr, for critical temperature of 28 F and relative humidity of about 70%. [1]

Wind speed Min. temp. ^{O}F	0-1 mph	2-4 mph	5-8 mph	9-14 mph
27	0.10	0.11	0.14	0.16
26	0.10	0.13	0.16	0.17
25	0.10	0.14	0.18	0.21
22	0.10	0.18	0.24	0.29
20	0.11	0.21	0.28	0.34
18	0.12	0.23	0.31	0.38
15	0.13	0.26	0.35	0.43

By Katherine Perry, from The Strawberry Grower, Vol. 5 No.2, Feb. 1998

Special equipment recommended. It is strongly recommended that you purchase a digital thermometer unit for thermocouple blossom temperature measurement, or obtain wet bulb temperature information (from a weather forecast service like AWIS, Inc., or purchase a sling psychrometer for wet bulb and dry bulb measurement), for frost/freeze protection under medium to high wind conditions.

Step 1. Check out your overhead irrigation system at least 2-weeks ahead of when it may be actually needed for strawberry frost/freeze protection to allow time for making any needed adjustments and repairs in the lines and pumps. This is also the time to evaluate certain performance characteristics of your sprinkler system, including overlap of sprinkler patterns (a 40 ft x 40 ft sprinkler spacing will provide greater uniformity of application under windy conditions than traditional 60 ft x 60 ft settings), sprinkler rotation speed (you want at least one revolution per minute), and to make sure that the actual sprinkler discharge rates are within the manufacturer's specified ranges. By doing test runs with your system you can verify actual sprinkler discharge rates for different sprinkler nozzles and pressures.

Step 2. Obtain reliable minimum temperature information for the forecasted frost/freeze event. Be sure to adjust weather service minimum temperature forecasts for your location. Minimum temperatures can vary by as much as 15 degrees at night over small distances. It is also important to know that at the ground level, the strawberry plant canopy and blossom temperatures can be significantly lower than temperatures being forecasted for a weather shelter height of 5 ft. This difference is pronounced on nights when there is very little wind, low humidity and clear skies - one more excellent reason to purchase a digital thermometer with thermocouple temperature measuring devices that insert into the blossom!

Step 3. Consult forecasted **wind speeds**. Unfortunately, this information is often not as dependable temperature forecasts.

Step 4. Use the minimum temperature forecast and the wind speed forecast to identify in **Table 5** the maximum sprinkling (precipitation) rate needed with 70% relative humidity (Temp x Wind Precipitation Tables for Higher and Lower Humidity can be obtained from your local County Extension Center, or on www.berryalert.org). Strawberry plasticulture overhead sprinkler irrigation systems are designed to provide a range of precipitation rates from as little as 0.10 to 0.25 inch/acre/hr. Under medium wind conditions of 5 to 8 MPH, for example, you can see in Table 5 that a precipitation rate of 0.24 inch/acre/hr is needed for a temperature minimum of 22 ^{o}F.

Don't be fooled by wind forecasts! Regrettably, the unreliable nature of wind speed forecasts makes it nearly impossible to be sure of the highest sprinkling rate that will be needed. If winds of in excess of 9 MPH are being forecasted in conjunction with projected minimum temperatures at the plant canopy of 20^{o}F (requiring a precipitation rate of 0.34 inch/hr/acre), you might conclude that your irrigation system does not have adequate capacity under such conditions if your maximum rate is 0.25 inch/hr/acre. But, in many instances, actual winds are significantly less than forecasted. *It is always better to be ready to apply water in the event of an overstated wind speed forecast.* At the minimum, you should apply row covers if you are in heavy bloom, and you are personally convinced that your irrigation system cannot produce the required rate of sprinkling for the minimum temperature x winds being forecasted. "Doing nothing" when the strawberry crop is at, or near full bloom, is not a desirable option with so much crop at risk in a frost/freeze.

Special situation during bloom. Perhaps the most challenging situation that can arise is when you have numerous open blossoms/plant, and winds are in excess of 14 MPH. Under these circumstances, it may be best to irrigate on top of the row covers in an attempt to save the open blossoms. Our experience with this technique is quite limited, but if you are able to keep your irrigation system functioning all through the night and early morning, there is a good potential of saving many of the open blossoms, most of the popcorn blossoms and virtually all of the emerged flower buds.

Step 4. Watch wet bulb temperatures to determine when to start irrigation. Start watering before the *wet bulb temperature* reaches the critical blossom temperature of 30 F, even though the air temperature (dry bulb) may be well above the wet bulb temperature. For example, on March 12, 2004, there was a frost/freeze in Raleigh, North Carolina, that required a start-up time of around 1 am in the morning, as this was the time that AWIS, Inc., was forecasting that the wet bulb temperature in this location would be 30 F. At this same hour, the dry bulb temperature was forecasted to be 35 F, and the dew point temperature was 21 F (the wet bulb temperature is between the dew point and dry bulb temperatures and normally closer to dry bulb).

In years past, many growers would have waited another 2 hours to start watering, as the forecasted air temperature of 33 F (dry bulb) was not expected until about 3 am. However, if the grower had waited on this night to start watering at a dry bulb temperature of 33 F, the wet bulb temperature was forecast to be 29 F at this same hour (3am). By waiting this long, the grower would risk injuring the crop to a phenomenon that is commonly called the 'cold jolt.' To understand the 'cold jolt,' you need to know that the *wet bulb temperature* is the temperature air cools to when water is added. As soon as you start irrigating, the blossoms actually drop in temperature to the wet bulb temperature. Knowing this, you can appreciate the danger involved with starting at a wet bulb air temperature of 29 F, as this temperature is 1 degree lower than the critical temperature (30 F for the open blossom).

You can avoid the 'cold jolt' entirely by starting before the wet bulb temperature of 30 F is reached. On this particular night (3-12-04), it meant starting the irrigation system up at around 12:30 am when the wet bulb was around 31 F. You may not see any ice forming in the first half hour to 45 minutes after starting up, but this not a big problem. It is far better to waste 30+ minutes of extra irrigating early in the evening, than to risk exposing blossoms to wet temperatures that could cause them to drop below their critical temperature for survival.

Step 5. Monitoring the irrigation system while running.

- *Applying water at an inadequate rate* can result in greater damage to the crop than applying no water at all! If ice-making is occurring too fast (this traps air bubbles in the ice and gives a milky appearance), then you will be cooling the crop to a lower temperature than it would have reached had you done nothing. If you see the formation of "milky ice," it is essential to *increase precipitation rates*.
- If you make a commitment to sprinkling in a windy conditions, you must do everything possible to keep sprinklers rotating so that all blossoms are being re-wetted at least every 60 seconds. If irrigating under high winds you can expect to get frequent icing up and clogging of sprinkler nozzles. If the sprinkler nozzles remain clogged for a half hour, or more, you can anticipate severe cold injury to not only all flower stages, but possibly leaves as well. With an extended period of shutdown (hour or more), there could be extensive damage to plant crowns and the flower buds inside the crowns.

Step 6. Shutting down the irrigation system.

- Thermocouple blossom temperatures are excellent for removing all of the guesswork associated with the decision as to when it is safe to turn off the irrigation system, which is a very difficult decision to make on some occasions, especially when dew point temperatures are very low and winds pick up in early morning. When all the blossom thermocouple temperatures read 32^{o}F, or above, it is safe to shut down. You must take blossom temperature readings in the coldest part of the field, and on the shadier side of the double row, to be sure that you are not shutting down too early.
- Wet bulb temperature can be used to safely determine when sprinkling can be shutdown in the morning – water can be safely turned off when the wet bulb temperature is above 32^{o}F.
- Waiting for all of the ice to melt is an older method that was once thought to be the most reliable method, but it has a number of shortcomings. First, because you are running later into the morning, this method is wasteful of water and fuel. It is also very exhausting for the operator to be running later than necessary. In some cases, winds pick up very briskly in the early morning, and by irrigating into these

high winds, most of the water is having cooling effect, and this will actually inhibit the ice from melting and make you think that it is necessary to keep irrigating late into the morning, or even early afternoon.

Frost/freeze protection with light winds (or no winds), and low humidity

Without as much concern for winds, lower rates of sprinkler irrigation can be used on nights with relatively calm winds (Table 5). However, anything that promotes evaporation, such as low humidity and high wind speed, will also promote overall blossom cooling. Dew point temperature is a good way to describe the humidity or amount of water vapor in the air, and it has great practical value to strawberry growers because it will tell you whether frost can be expected to form near the freezing point (32 F), or not. When the dew point is below 32 F, it is often called the *frost point* because frost can form when the temperature is below freezing. Basically, the drier the air, the great the potential for frost to form at temperatures below 32^{o}F (this is known as a *black frost*, in which few or no ice crystals form because the air in the lower atmosphere is too dry).

If the dew point is in the mid 20s, for example, you will not be able to see (or feel) any frost forming on the plant surface until the air temperature drops into the mid 20's. A grower who relies on seeing evidence of frost on the leaves before starting up his irrigation system, will not be able to detect any frost until the air temperature reaches the dew point *(frost point)* of 25 F. Unfortunately, the blossom will have already been killed (and, thus the name *black* frost), by waiting until the actual frost point is reached to start irrigating as the critical damaging temperature for an open blossom is around 30 F.

Margin of safety needed on low dew point nights for starting irrigation. In the absence of having access to wet bulb temperature information, or access to a digital thermometer and thermocouples for taking direct blossom temperatures, you can utilize dew point temperature information to give you a reasonably good idea as to when to turn the sprinklers on for low humidity nights. If the dew point is in the low to mid 20s, and air temperatures are dropping at an average of dropping at 2^{o}F per hour, then sprinkling should begin at around 34^{o}F. With dew points in the upper teens, and cooling rate of around 3^{o}F per hour, then a safe turn-on temperature will be around 35^{o}F. On occasion, we have encountered dew point temperatures in the low teens and single digits (when very cold and dry air masses from Canada move into the region), and in these situations we have experienced temperature drops of as much as 6 ^{o}F per hour – under these conditions it is vital to provide an even greater safety margin, and irrigating needs to start at 37 ^{o} F to 38 ^{o} F (this can mean starting irrigation even a half hour *before* sunset).

Frost protection

Dew point temperature is not only useful for determining the potential for a *black frost,* but it can also give you a 'heads-up' call when weather conditions favor a white frost (also called a *hoar frost*), that results when atmospheric moisture freezes in small crystals on solid surfaces. White frost can form at the ground level (strawberry canopy) when dew point temperatures and air temperatures are in the upper 30s at the standard weather shelter height of five feet. Whenever there is *any* potential for patchy and scattered frost, strawberry growers must be prepared to frost protect with sprinkler irrigation. The formation of ice crystals on strawberry blossoms can be very damaging, and the grower's objective is to prevent frost formation on the strawberry blossom with watering. Ideal dew point temperatures for widespread white frost formation are in the upper 20s to lower 30s. When this occurs with freezing air temperatures, there is potential for heavy white frost and catastrophic damage to blossoms. The bottom line for the strawberry grower is to prevent frost from forming on the blossoms. It is an excellent idea to have your frost alarm at your house set at 38 ^{o}F on nights when there is potential for frost formation at the ground level. Once you are in the field, you can begin to monitor temperatures more closely and check for the beginning of any frost formation on leaves. Begin irrigating as soon as you see evidence that blossom temperatures appear to be going below their critical temperature of 30^{o}F, or upon seeing evidence of any frost formation on the plant canopy. Keep checking blossom temperatures, or liquid-in-glass thermometer readings from within the canopy area every 15 to 30 minutes. Record the observations. You can determine from a graph what the cooling rate is (graph the temperature as the *x axis*, and time as the *y* axis), and when the temperature is likely to go below the critical open blossom temperature of 30^{o}F. If winds pick up, or a cloud cover moves in, this will inhibit frost formation and slow blossom cooling, and sprinkling may not be necessary on nights when either of these conditions occur. A safe turn on blossom temperature is 32^{o} F when there is no wind and the dew point temperature is in the upper 20s. If you are using a liquid-in-glass thermometer reading, a safe turn on temperature is 33 F. A blossom temperature of 32^{o}F often relates to a liquid-in-glass thermometer reading of 33^{o}F. If you do go ahead with sprinkling, be sure to continue watering until all blossom temperatures are at 32^{o}F, or higher. You may choose to wait until most of the ice is melting if you do not have a digital thermometer to verify that open blossom temperatures are at 32^{o}F, or higher, for shutdown in the morning. On most frost protection mornings, it is common to be shutting down the irrigation system at about 7:30 to 8:00 am.