



Protecting Blueberries from Freezes in Florida ¹

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Dormancy and Cold Hardiness

Most temperate zone plants, including blueberry, enter a dormant period during late fall and winter characterized by no growth and greatly reduced metabolic activity of above ground parts. This dormant condition is a defense mechanism which enables plants to survive cold. The development of dormancy and cold hardiness is a gradual process which begins in late fall or early winter in Florida. In response to shorter days and lower temperatures during the fall, growth of blueberry plants slows, dormancy begins to develop, and cold hardiness increases. Even before cold temperatures occur, blueberries develop a certain amount of cold hardiness. Exposure to cool temperatures greatly accelerates dormancy development and increases cold hardiness. Later in the winter, as temperatures continue to drop, cold hardiness continues to increase. Fully dormant blueberry plants are quite cold hardy and seldom suffer serious damage from cold weather in Florida.

Once fully dormant, a blueberry plant must be exposed to a period of cool temperatures before it will break dormancy and grow normally the following spring. This is a result of its chilling requirement. Each cultivar has its own characteristic chilling

requirement. The amount of chilling that blueberry plants receive in Florida varies considerably from year to year. Temperatures needed to satisfy the chilling requirement are generally considered to be between 32°F and 45°F. However, keeping track of chill hours is more complicated than merely recording the number of hours between 32°F and 45°F. Exposure to one hour of temperatures either slightly above or below the optimum chilling temperature can result in some chill accumulation. The farther from the optimum temperature, the smaller the fraction. At temperatures below freezing, no chilling accumulation occurs. Loss of accumulated chilling can occur with exposure to very warm temperatures. Temperatures between 32°F and 45°F appear to be most effective at satisfying the chilling requirement of blueberries, but temperatures between 45°F and 55°F contribute something to chilling and temperatures above 70°F between mid-November and mid-February probably negate some chilling.

Another factor which can affect chill accumulation in blueberries is the presence of leaves during chilling. Blueberry plants in Florida often retain some of their leaves throughout much of the winter, especially in southern Florida. These plants

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will not accumulate chilling as quickly as defoliated plants.

Once chilling is satisfied, warm temperatures cause vegetative and floral buds to initiate growth. In Florida, most blueberry cultivars initiate flower bud growth before vegetative bud growth. As flower buds pass through the developmental stages from dormant buds to fully open flowers, they become more susceptible to cold. Experiments suggest that swollen rabbiteye flowers (Spiers stage 3) can withstand temperatures as low as 25°F, but some may be killed at 21°F, or lower. Buds which had opened to the point where individual flowers were distinguishable can be killed by temperatures of 25°F, and buds with expanded corollas are often damaged or killed at 28°F. Even a slight freeze can cause severe damage to fully open flower buds.

Freezes and Freeze Protection

Freezes during February, March, and April are a much greater problem for Florida blueberry growers than was anticipated 20 years ago. With a shift toward earlier-ripening cultivars, both rabbiteye and southern highbush blueberry crop losses from freezes have increased significantly. This is compounded by the fact that many blueberry plantings have been established in cold pockets to take advantage of soils that are higher in organic matter. Today, freezes are probably the number one production problem for Florida blueberry growers.

Several factors affect the severity of damage to blueberry plants, flowers, and fruit in particular freezes. Some of these factors are fairly well understood; others have received little study.

Temperature, Wind Speed, and Dew Point

A low dew point is always worse than a high dew point. Dry air loses heat faster after sunset. Water vapor in all levels of the atmosphere radiates heat to the earth's surface and partially off-sets the heat being lost by radiation from the ground. Moist air increases the amount of frost formed and increases the amount of latent heat released in the field at night. If the air is very dry and there is not much wind, flowers can become several degrees colder than the air, and low humidity increases evaporative cooling

when irrigation is run. Wind can be bad or good. If overhead irrigation is being applied, wind is a serious problem, because it increases evaporative cooling, removes heat from the field, and interferes with the even distribution of the water. If water is not being applied, the wind is beneficial. It prevents formation of a cold pool of air near the ground beneath the inversion and it prevents the flowers and berries from becoming colder than the air that surrounds them. On still nights, flowers and berries lose heat faster than the air and become colder than the air. Open blueberry flowers have sometimes survived temperatures as low as 26°F when the wind blew steadily through the night with no calm periods, whereas flowers in the same stage of development are often killed at 28°F when there is little or no wind and the dew point is below 26°F.

Plant Tissue and Stage of Hardiness

Young blueberry plants are sometimes damaged in field nurseries during late fall and winter if they have not been properly hardened. New spring vegetative flushes can be killed by the same temperatures that kill open flowers and fruit. Completely dormant branches and flower buds are very cold-hardy in midwinter. However, any January warmth promotes growth and expansion of the flower buds, and some loss of hardiness accompanies each subsequent stage of flower bud development. Styles, ovary tissue, ovules, corollas, and pedicels are similar in their freezing points, but some marginal freezes may kill the styles but not the corollas, or the ovules but not the ovaries. The relative sensitivity of these organs seems to vary from one freeze to another. A partial crop can sometimes be rescued by spraying gibberellic acid on the ovaries of flowers whose styles or ovules have been killed by marginal freezes. However, GA-rescued fruit develop slower, produce smaller berries, and ripen later than fruit with viable ovaries which makes the rescued crop much less profitable for Florida growers who rely on high prices for early-market fresh fruit. If the dew point is high, and the temperature is only slightly below freezing, open blueberry flowers may be heavily coated with frost with no damage to any flower parts. On the other hand, if the air is dry, flowers may be killed with no frost on the plants, even on still nights.

Physical Conditions in the Field

Pine bark mulch culture can lower the air temperature at flower level in blueberry fields by as much as 5°F on calm nights with low dew points. Pine bark beds on hillsides with excellent air drainage would probably be less problematic. If the dew point is high, the pine bark has less cooling effect. The effect of thoroughly wetting the pine bark the afternoon before the freeze has not been studied. Dry soil and any weeds, alive or dead, lower the temperature in the field. Any object in the field on which frost can form, might be expected to lower the temperature of the blueberry plants by contributing to the dehydration of the air during the night. Dry soil lowers the temperature compared to wet soil by two mechanisms. First, dry soil provides little moisture to replenish the water vapor that is lost from the air by frost formation. This allows the temperature and dew point in the field to continue to fall after dew and frost begin to form. Second, dry soil conducts heat poorly from the warm depths of the soil to the cold surface. Wet soil has been reported to have a temperature conductivity approximately 8 times greater than that of dry sand. The lay of the land, with respect to elevation and air drainage patterns, greatly affects field temperatures on calm nights with low dew point, but is less important as the wind and/or dew point increase.

Weather Conditioning Before the Freeze

The ability of citrus leaves and stems to harden in response to several weeks during which night temperatures fall below about 50°F before a freeze is well known. Experienced blueberry growers are convinced that blueberry flowers and flower buds at all stages of development also have some ability to increase their cold hardiness in response to cold days preceding the freeze. This phenomenon merits further study in blueberry.

Blueberry Variety

It has long been known by growers that flowers and developing flower buds of rabbiteye blueberry (*Vaccinium ashei* Reade) are less cold hardy than highbush buds and flowers at the same stages of development. Among southern highbush cultivars, which are advanced-generation interspecific hybrids

between a deciduous, northern blueberry species (*Vaccinium corymbosum* from New Jersey) and an evergreen blueberry species from the Florida peninsula (*V. darrowi* Camp), there appears to be wide variation in flower bud cold tolerance. Just prior to anthesis, the range in killing temperatures of flowers of different varieties at similar stages of development in the field appears to be on the order of 2 or 3°F.

Passive Freeze Protection

Several strategies can be used to reduce crop loss from freezes. Some are more practical than others.

Cultivar Selection

The freeze risk to a blueberry crop can be reduced greatly by planting cultivars that flower late. For example, late-flowering rabbiteye cultivars such as Powderblue, Brightwell and Tifblue seldom suffer significant crop damage from freezes at the research farm in Gainesville. However, over a period of many years at the same location, Sharpblue, Misty and other early-flowering southern highbush cultivars averaged losses over 60% unless they were protected with overhead irrigation. Unfortunately, late-flowering cultivars tend to ripen later than those that flower early, and, at present, cultivars that ripen before prices fall around May 20 usually flower before the last hard freezes on north Florida farmland.

Site Selection

Both advective and radiation freezes have damaged blueberry fruit and flowers in Florida. Advective freezes occur when a cold air mass moves rapidly into Florida, usually accompanied by moderate to high winds. During an advective freeze, temperatures at a particular latitude in Florida tend to be similar from farm to farm. The exception might be for areas located immediately down wind from a large lake, which could be a few degrees warmer than surrounding areas. During an advective freeze, temperatures are gradually warmer the farther southeast you are in peninsular Florida. The farther south and east, the less likely it is that temperatures will be low enough to freeze berries while the wind is blowing. This is important because the combination

of wind and freezing temperatures is the hardest situation to combat when cold protecting blueberries.

Radiation freezes occur on clear, cold nights when there is little or no wind. Heat is radiated from the Earth to the open sky. Under these conditions, large temperature differences can develop over short distances due to differences in elevation. Hill tops may be 5 to 10 degrees F warmer than low ground at the same latitude. Hilltops in the northern part of peninsular Florida may be warmer than cold pockets 200 miles farther south. Traditionally, Florida blueberry farms have been planted on low, cold land because soils there are high in organic matter. There is increasing interest in planting blueberries on high ridge land, circumventing the soil problem either by growing plants in pine bark, or by adding enough peat to the soil to obtain good growth.

Pruning

If done at the right time of the year, pruning can delay flowering by 1 to 2 weeks. Growers who often lose their crops in freezes can delay flowering by pruning immediately after harvest and providing conditions that promote vegetative growth during summer and fall. Flower buds produced on vigorous shoots that result from pruning in late May and early June will mature later in the fall and flower later the following spring.

Freeze Protection Methods

Overhead irrigation systems, designed for freeze protection with diesel, rather than electric, pumps are the most widely used and practical method of reducing blueberry fruit losses to freezes in Florida (Fig. 1). Large volumes of water must be pumped to get good protection. The number of gallons per minute needed to protect one acre depends on the temperature, wind speed, relative humidity, and the design of the system. Table 1 adapted from Gerber and Martsof (Circular 287, Florida Agricultural Extension Service) attempts to describe the relationships between minimum temperature/wind speed combinations and water application rates needed for protection during a freeze. However, this table does not consider the water vapor content of the air. With unusually dry air, higher water application rates will be needed than

indicated by the table. In Alachua county, blueberry crops have occasionally been lost between February 20 and March 20, even in fields protected with overhead irrigation at a rate of 0.2 inches per hour. Temperatures of 26°F combined with 15 mph winds and low humidities exceed the protection capabilities of such a system, even though the same amount of water would protect flowers down to 18°F with no wind.



Figure 1. Blueberry field protected with overhead irrigation during a freeze.

Some growers have designed systems that can be quickly altered to deliver 0.4 inch of water per hour by changing riser heads. A practical system might be able to deliver 0.25 inch per hour over 10 acres or 0.4 inch per hour over 6 acres. In most years, the entire 10 acres could be protected. In years with severe late freezes, 4 acres could be allowed to freeze so that the other 6 acres could be given maximum protection. Before installing an irrigation system, seek advice from an irrigation specialist.

Best use of an irrigation system for freeze protection requires experience and close attention to the weather. Blueberry flowers and fruit will not freeze if temperatures in a weather bureau shelter located alongside the plants at the same height as the flowers stay 32 degrees F or above. Frost on the grass between the rows does not necessarily mean that flowers are damaged since on humid nights, frost can form when temperatures in the weather shelter are as high as 36 degrees F. With a clear sky and no wind, a thermometer placed open to the sky will read about 2°F colder than the same thermometer at the same height in a weather shelter. By placing several thermometers throughout a blueberry field, one can learn a lot about the temperature distribution patterns in that field during radiation freezes.

If or when to turn on the irrigation system during a cold night can sometimes be difficult decisions to make. The answer depends on such factors as the capabilities of the irrigation system, state of development of the crop, relative humidity, temperature, and wind speed. Some of these factors can not be predicted with certainty. The following guidelines should be helpful in most but not necessarily in every situation. First, the system should not be used on nights where the temperature-wind combination produces conditions more extreme than the system was designed to handle. Refer to a reliable forecast and Table 1 to determine whether or not the system should be used.

Calm Nights

If there is no wind predicted and a decision is made to run the system, it is usually turned on when a thermometer, hung under the open sky from a bare branch in the coldest part of the field reaches 32°F. However, if the dew point temperature is below 25°F, the system should be turned on at 34°F, which will probably be only about half an hour before the temperature reaches 32°F. The temperature has a great tendency to fall to within 1 degree of the dew point on clear, calm nights. If the dew point is 26°F or lower and frost forms on flowers or berries, they will be killed. If the dew point temperature is 30°F or above and frost forms on flowers or berries, they may not be damaged. During the morning following

the freeze, if there is no wind and the sun is shining brightly, the irrigation can be turned off when icicles are falling rapidly from the plants and have been falling for more than half an hour. Never turn off the irrigation before icicles are falling no matter what the temperature. If the dew point temperature is below 20°F, continue running irrigation until the shaded air temperature rises to 40°F. If it is windy and the dew point is 26°F or below, do not turn off the irrigation until most of the icicles have fallen.

Windy Nights

For windy freezes, the decisions about whether or not to run irrigation become complicated. Table 1 provides guidelines for determining the amount of water required to protect fruit at various temperature/wind speed combinations. However, the values in Table 1 assume normal relative humidity. If relative humidity is very low, as sometimes happens when a cold dry air mass moves into Florida, the values in Table 1 may underestimate the amount of water needed for adequate freeze protection. Paying attention to the dew point temperatures during various nights of freeze protection will help take the mystery out of why crops are sometimes saved when it seemed too cold and windy and why crops may be lost when it seemed they should have been saved.

Overhead Irrigation the Afternoon or Evening Before a Freeze

Experienced fruit growers have long known that irrigating their fields the afternoon before an expected freeze can sometimes reduce the damage caused by the freeze. There are four situations in which this practice is potentially useful to blueberry growers.

First Situation

It is a calm afternoon, and minimum temperatures are forecast to be on the borderline between damaging and safe. A wet ground may allow

the grower to avoid having to turn on the system during the night. In such situations, even minimum overhead irrigation during the night should be effective in preventing damage, but there are disadvantages to irrigating on frost nights, and being able to avoid a run is highly desirable. If the temperature does become critical during the night, a wet ground will reduce the probability that damage will occur before the system is turned on.

Second Situation

The dew point is low and the wind speed is expected to be erratic during the night. Or, temperatures are expected to fall to or below the damaging point with light winds, with a rising wind expected later in the night. Even though a rising wind in the night is frequently bringing in colder, drier air behind a secondary cold front, the effect may be to raise the temperature of the blueberry flowers, as cold surface air is mixed with warmer air above the inversion and the wind raises the flower temperature to the temperature of the surrounding air. On some occasions, growers may be able to protect the crop with overhead irrigation before the wind increases, but lose the crop due to evaporative cooling after the wind begins. On the other hand, dry plants might have survived the cold wind without damage, but could not survive the lower temperatures that occurred before the wind broke the inversion. On some such nights, fields that have been thoroughly wet late in the afternoon before the freeze have escaped damage because a higher temperature was maintained before the wind began, whereas crops were lost in dry fields that were not irrigated at all and in fields in which irrigation was run throughout the night.

Third Situation

The grower lacks sufficient pumping capacity to protect the entire acreage against a freeze of the expected severity. A decision is made to change the sprinkler heads to a larger orifice diameter in half of the field and close off the valve to the other half. It may be possible to reduce damage in the half that cannot be irrigated during the night by thoroughly wetting the soil during the afternoon before the freeze.

Fourth Situation

This may be the most common situation in which growers could improve their crops by adopting a practice that is seldom being used at present. Frequently, during January and early February, after blueberry flower buds have begun to swell in response to warm periods in the winter, a freeze will occur in which the dew point is so low, the air so cold, and the probability of some wind during the night so high that no experienced grower would choose to run the irrigation at night for fear of causing massive damage from evaporative cooling, frozen emitters, broken branches, and uprooted plants. Furthermore, many of the flower buds may still be quite dormant, and will survive if nothing is done. Frequently, in late January, the flower buds may show a wide range of developmental stages. For example, 20% of the buds might be killed if the temperature falls to 24°F, an additional 20% will be killed if it falls to 21°F, an additional 20% will be killed at 18°F, and 20% would survive 16°F. A low-risk strategy for the grower would be to thoroughly wet the ground the afternoon before freezing temperatures began, with the goal of raising minimum temperatures in the field by two or three degrees and reducing the fraction of the crop lost. Because fruit prices are often higher in years with light crops, and because blueberry plants can sometimes partially compensate losses in fruit number by increasing fruit size, saving part of the crop could be quite rewarding for the grower.

Alternative Freeze Protection Methods

Wind machines and helicopters have been used to some extent to protect blueberry crops from freezes in Florida. Both are based on the fact that on clear calm nights a strong temperature inversion develops, in which temperatures within 6 feet of the ground may become much colder than temperatures 50 to 100 feet above the ground. By mixing these air layers, wind can raise the temperature near the ground by about 4°F, the exact amount varying with the strength of the temperature inversion and the effectiveness of the air mixing. On nights with wind, wind machines and helicopters cannot warm an orchard because no temperature inversion develops.

Many windy freezes occur in Florida during January and February which usually coincides with the southern highbush bloom period.

A single wind machine will normally provide a maximum heating of about 5°F over an area of about 10 acres. The cost of installing and maintaining a wind machine is fairly high, but the cost of running one is comparatively low, about eight gallons of gasoline per hour. A single helicopter can provide a similar degree of heating over an area of about 40 acres, so long as it is constantly flying. A problem with helicopters, apart from their high cost, is how to keep them continuously in the air on freeze nights. Scheduling problems, pilot fatigue, mechanical breakdowns, and the need to refuel can interrupt service. Wind machines are commonly used in some fruit producing areas of the World. They are seldom used on blueberries in Florida but might be practical at the south end of the production area in Florida.

Orchard heaters, which burn fuel oil, were widely used to protect citrus trees from freezing before fuel prices became prohibitive. They are also effective, but expensive, in protecting blueberry crops. On a still night, 24 grove heaters per acre will heat a citrus grove by about 5°F. These heaters burn a gallon of fuel per hour and fuel costs can be over \$300 per acre for a single night. High fuel costs have prevented widespread use of grove heaters for freeze protection in Florida blueberries.

Table 1. Suggested overhead irrigation application rates for cold protection of blueberries under different wind and temperature conditions.

Minimum Temperature Expected	Wind Speed in M.P.H.			
	0 to 1	2 to 4	5 to 8	10 to 12
	Application Rate (inches/hour)			
27 °F	0.10	0.10	0.10	0.1
26 °F	0.10	0.10	0.14	0.2
24 °F	0.10	0.16	0.3	0.4
22 °F	0.12	0.24	0.5	0.6
20 °F	0.16	0.3	0.6	0.8
18 °F	0.20	0.4	0.7	1.0
15 °F	0.26	0.5	0.9	---
¹ Dry air accompanied by wind will require higher application rates than indicated for a given temperature/wind speed combination. From Gerber and Martsolf, Extension Circular 287, Florida Agricultural Extension Service.				