Summary

The SWFREC blueberry planting has demonstrated that southern highbush cultivars will produce fruit of acceptable yield and quality in the south Florida climate. Compost proved to be a better soil amendment than peat for adding organic matter. Of the commercially-available cultivars tested, both ‘Gulf Coast’ and ‘Sharpblue’ would be candidates for commercial plantings. Of the numbered selections evaluated, 87-108, 87-220, and 87-223 performed the best. The 87-108 cultivar yielded 2.5 times more fruit than ‘Gulf Coast’ and ‘Sharpblue’ in 1998, and has been a vigorous, prolific producer each year. Its main drawback that could keep it from becoming a significant commercial variety is a picking scar that tears easily and is somewhat “leaky.”

FREEZE PROTECTING FLORIDA BLUEBERRIES

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Additional index words. Vaccinium species, cold protection, overhead irrigation, agricultural meteorology, weather.

Abstract. Blueberries are grown commercially in Florida from La Belle north. The plants are cold-hardy if dormant, but lose cold-hardiness as they come out of dormancy from late January through April. Growers use overhead irrigation to protect the flowers, fruit, and tender spring vegetation from freezes. Critical temperatures below which protection will be needed depend on wind speed, dew point, and the stage of development of the flowers and fruit. Cultivars vary in cold tolerance, even when they appear to be at the same stage of flower development. Pine-bark mulch, dry soils, grass strips between the rows, and planting in ‘frost pockets’ can increase freeze damage on nights with clear skies, light winds, and low dew point. During severe freezes, with low temperatures, high winds, and low dew point, use of overhead irrigation can increase damage to the crop. Overhead irrigation should not be used if evaporative cooling would exceed the heat produced by ice formation. Thoroughly wetting the ground just prior to the freeze can be useful on certain nights when it is too cold to irrigate during the freeze.

Southern highbush blueberries are grown commercially in Florida from La Belle north to the Georgia line, with most of the production in the area from Plant City to Jacksonville. There is also increasing acreage of southern highbush blueberry in southeastern Georgia around Homerville. The goal of Florida blueberry growers is to harvest blueberries for the fresh market from 1 April to 15 May. During this period, Florida weather is favorable for producing and harvesting high-quality fruit. Cool nights and warm, sunny days increase berry firmness and Brix. Humidity is low, and any dew on the berries dries quickly after sunrise. Extended rains that delay harvest and split the berries are rare. Temperatures are comfortable for workers hand-harvesting the fruit. This season also comes between the end of blueberry harvest in Chile (the major exporter of fresh blueberries to the U.S. from November to March) and the beginning of harvest in the first major production area to the north (southeastern North Carolina about 20 May).

The blueberry varieties grown in Florida require 50 to 70 days to ripen after the flowers open (Lyrene, 1989). The length of this period depends on the variety, and is shortest when the plants are vigorous, heavily leafed, and are carrying a light crop, and when temperatures are above normal during the period between flowering and fruit ripening. Extended cool periods after flowering greatly delay maturation.

Blueberries that ripen in early April come from flowers that are pollinated in early February. Blueberry flowers become vulnerable to hard freezes several weeks before they are pollinated and can be killed by hard freezes in late January. Thus, blueberry flowers in Florida that are not protected from cold are frequently killed by freezes, and yields are often reduced. Overhead irrigation is currently the only method of freeze protection widely used in Florida by commercial blueberry growers. The ice load that accumulates during freeze protection is less damaging to blueberry plants than to citrus. Blueberry plants are more supple than citrus; they also have fewer leaves during the season when freeze protection is needed and accumulate a smaller ice load. Information on the use of overhead irrigation to protect various crops from freezes was presented by Harrison et al., 1972.

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Florida Agricultural Experiment Station Journal Series No. N-01912.


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Moving Blueberry Production Farther South

One way to reduce freeze damage to blueberries would be to move the production area farther south and onto warmer sites, as was done with citrus after the freezes of the 1980s. Unfortunately for this idea, the best blueberry varieties now available have winter-chilling requirements that make them best adapted to north-central and northeast Florida. If the flowers do not get frozen, these varieties give higher yields in Gainesville, Florida and in Valdosta, Georgia than they do in Sebring and Lake Placid. Use of the dormancy-breaking compound, Dormex® (hydrogen cyanamide), and development of lower-chill varieties will improve the competitive situation of the south, but the benefits of colder winters will keep the northern production areas competitive despite the greater freeze losses. Protecting blueberry flowers and fruit from freezes with water from February through 1 April is important in the south, but is even more important and considerably more difficult in north Florida.

Irrigation Design

Details on irrigation design should be sought elsewhere. Most Florida blueberry growers use deep wells and diesel pumps, with riser spacings of 40 feet x 40 feet, and the ability to apply water at 0.20 to 0.40 inches per hour. Application rates higher than 0.20 inch per hour increase costs but give added protection in severe freezes. Diesel pumps are favored over electric because they are not vulnerable to electrical interruptions and because the water pressure (application rate) can be adjusted by throttling the engine up as the temperature falls. Well water, being warmer than surface water in severe freezes, is thought to reduce the problem of frozen emitters. How important the difference is has not been determined.

Protecting Blueberries from Freezes with Water in Florida

It might be expected that protecting the blueberry crop from freezes with overhead irrigation would be easier and more effective in Florida than in North Carolina and New Jersey. Such is not the case. The reason is that Florida growers must protect their crops during February and March, whereas in North Carolina almost all freeze damage to blueberries occurs after April 1. By April, the 24-hour sun has risen in the Arctic, the temperature contrast between the Arctic and the equator has lessened, and the powerful cyclones that sweep from west to east across North America during the winter, dragging their arctic fronts behind them, have weakened and are following a more northerly track. By April 1, most killing freezes in the southeastern U.S. occur on nights with little wind and with dew points only slightly below freezing. In contrast, Florida growers trying to protect blueberry flowers during February and early March may face temperatures below 28°F, winds gusting over 10 mph, and dew-point temperatures substantially below air temperatures. In this situation, unless a very large volume of water is continuously applied, heat loss from evaporation will exceed heat gain from freezing water, and the overall effect of irrigation will be to lower the temperature in the field rather than to raise it. Insufficient irrigation on windy nights with low dew points has sometimes resulted in complete crop loss and severe plant damage, including cane death and substantial plant mortality. Not only must the Florida blueberry grower install a costly irrigation system, but he or she must also learn when to stand by and receive damage without turning on the system. As described later, there are times when the best plan is to thoroughly wet the field before freezing conditions begin and then turn the system off before conditions become extreme after sunset.

Temperatures in a Blueberry Field at Night

If the wind blows continuously all night, not falling below 5 mph for even one minute, the temperature of the air 1 foot above the ground will be the same as at 10 feet. This will be the same as the thermometer temperature measured 5 feet above the ground in a standard instrument shelter, which will be the same as the temperature indicated by an unsheltered thermometer hanging from a leafless branch 5 feet above the ground, which will be the same temperature as the petals and ovaries of the flowers and the surface of the berries. However, if the wind dies, even for one minute, no two of these temperatures will remain equal. The temperatures that matter, those of the petals and ovaries of the flowers and the temperature of the young berries, will not be accurately indicated by either the sheltered or unsheltered thermometer. With clear sky, no wind, and a low dew point, each item in the blueberry field will attain its own distinct temperature, depending on its location and on its ability to lose heat by radiation. Thus, the roof of a car parked in the field may become frosty (surface temperature below 32°F) before the sheltered thermometer (air temperature at 5 feet) reaches 40°F.

It is often given as a general guide that open flowers of blueberry and peach can survive temperatures down to about 28°F but not lower. However, we have seen fully open blueberry flowers undamaged when the temperature in a standard instrument shelter was below 26°F for more than one hour on a night when a strong wind blew continuously with no periods of calm. We have also seen blueberry flowers at the same stage of development destroyed by a freeze on a calm night with a low dew point when the same sheltered thermometer did not fall below 30°F. The simplest hypothesis to explain these observations is that open blueberry flowers with corollas still attached can survive flower temperatures as low as 26°F, but flower temperature, like the temperature of a car top, can fall below 26°F when the shelter temperature remains above 30°F if there is no wind and the dew point is very low.

Dew/frost Formation and its Effect on Temperatures in the Field

The following discussion refers to air temperatures 2 to 7 feet above the ground, where most blueberry flowers and fruit are located. The discussion assumes low-lying land with little local relief, which is typical of blueberry farms in Florida. If there is little or no wind, most temperature fall at night occurs because objects in the field are losing heat by radiation faster than they are absorbing heat from other radiating sources. The net rate of heat loss for any particular object depends on its physical properties, including density and molecular composition. Dry air is a very poor radiator, and loses heat only slowly at night. Almost every object in the field and on the ground loses heat faster than the air, and, in the absence of wind, objects in the field, including flowers and fruit, quickly become colder than the air that surrounds them. How much colder? The answer depends on the size, texture, and radiating ability of the object and on the wind speed and dew point temperature (Parsons, 1986) of the surrounding air.
Because many objects in the field are colder than the air at night, dew or frost form as the temperatures of the objects fall below the dew point temperature of the air. Formation of dew or frost liberates latent heat that was present in the water vapor, and greatly slows the rate of temperature fall in the field. This is why temperatures on clear nights with light winds normally fall rapidly until dew or frost begins to form, and thereafter fall much more slowly, normally only about 1°F per hour during the winter, and even less during the summer, when, because the air is warmer, a greater amount of dew condenses per 1 degree temperature drop. Unfortunately, in the absence of enough wind to mix the layers of air, formation of dew or frost quickly dehydrates the air in the field, preventing fog formation. If neither dew nor frost formed, the air near the ground would fall to its dew point temperature, preventing fog formation. If neither dew nor frost are forming on many objects in the field by the time the air temperature has fallen to about 1°F above its dew point. Condensation of dew or frost lowers the dew point of the air, and allows air temperature to continue to fall below the temperature that was its dew point earlier in the night. The decline in dew point in a blueberry field as a result of dew or frost formation can be more than 4°F (Petterssen, 1958, and personal observations).

**Wet Ground and Weed-Free Fields to Reduce the Fall in Dew Point Temperature**

The ground in the Florida peninsula, even during severe freezes, is seldom snow-covered or frozen. If the ground is wet at the surface and is wet to field capacity to a depth of 2 feet, it constitutes a large reservoir of heat and moisture that can help replenish the moisture lost from the air as frost forms. A cubic centimeter of moist soil can store as much heat (measured in cal/cm³/°C) as 1300 cubic centimeters of air (Petterssen, 1958). According to Petterssen, heat from as deep as 1.6 feet below the surface of moist soil will contribute significantly to the heating of the air at night, with the temperature of the soil at that depth falling during the night 5% as much as the temperature of the soil at the surface. For dry sand, the corresponding depth is only 0.6 feet. If the soil surface is moist, packed, and bare of vegetation, evaporation of moisture from the soil surface and the subsequent condensation of water vapor as frost will act as a pump that transfers heat from the soil to the plant surfaces and surrounding air. Evaporation from very moist soil may even raise the dew point of the surface air trapped beneath the inversion on a calm night, thus limiting the temperature fall in this inversion layer.

The effect of surface water on minimum temperatures was noted by a blueberry grower in Clinch County, near the Okfenekee Swamp, in southeast Georgia during the winter of 1999-2000 (Jerry Vanerwegen, personal communication). Due to a prolonged drought, most of the cypress ponds, which normally cover a large fraction of the county, were dry, and throughout the winter, minimum temperatures during radiation freezes frequently fell substantially below forecast values, often by 5°F or more, even though the same forecast service had been highly reliable in years when the cypress ponds were at their normal levels.

**Overhead Irrigation the Afternoon or Evening before the 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 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, so early in the year, 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
Factors that Affect Freeze Damage in Blueberry Fields

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.

1. 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 absorbs part of the heat radiated from the ground and radiates it back to the earth's surface. Moist air increases the amount of frost formed and increases the amount of latent heat released in the field at night. Dry air lowers the temperature the flower can attain at a given air temperature and increases evaporative cooling when irrigation is run (Lynne, 1996). 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, which occurs on still nights because flowers and berries lose heat rapidly from radiation and air loses heat only slowly.

2. Plant tissue and stage of hardiness. Young blueberry plants are sometimes damaged in field nurseries during the 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. 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.

3. Physical conditions in the field. Pine bark mulch lowers the air temperature at flower level in the field by as much as 5°F on calm nights with low dew points. If the dew point is high, the pine bark has less 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, in the field 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. 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. According to Petterssen (1958), wet soil has 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.

4. Conditioning weather before the freeze. The ability of citrus leaves and stems to harden in response to several weeks during which night temperatures fall below 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.

5. 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 previous 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.

Summary and Conclusions

Freezes in late fall or winter can damage or kill young blueberry nursery plants that are growing vigorously and have not hardened off. Hard freezes after the plants have renewed growth in the spring can kill new shoots. Stem blight can invade freeze-killed shoots and further damage or kill the plant.

The main threat from cold on blueberries in Florida, however, is to flowers and fruit. To counter the threat, growers install overhead irrigation systems, the size of which depends on the grower's estimation of the future value of the fruit, the probability of freezes of different levels of severity at his or her site, the cost of the system, and the availability of water.

Once an irrigation system has been installed, it is used on almost all calm nights when the fruit or flowers are threatened by cold. Over the past 20 years, the number of nights per year that have required protection has varied from 0 to 15 for various locations and various years in Florida. In a few years, the crops were largely lost in the Gainesville area in late February and early March due to freezes with temperatures too low, winds too strong, and air too dry to be countered by applying overhead irrigation at 0.3 inch per hour. If the night is windy and the dew point is below 25°F, it is usually best not to turn on an overhead irrigation system unless a very large volume of water can be applied.

Overhead irrigation is an important but partial solution to the freeze problem in Florida blueberries. No complete and easy solution is at hand. Lower-chill varieties that would improve blueberry yields in south Florida would allow the indus-
try to flee southward. Varieties that would thrive on hilltop soils in Florida would allow growers to abandon frosty, low areas. Use of pine-bark growing medium is a step in this direction, but pine bark itself makes the air much colder in the field on calm nights. Grafted blueberry plants, using the upland-adapted sparkleberry (Vaccinium arborescens Marsh.) as rootstock for highbush blueberry scions may be feasible, but would greatly increase plant costs. Development of varieties that require more heat to induce flowering and have a shorter flowering-to-ripening interval should yield progress. At present, however, growers must consider overhead irrigation and occasional crop losses among the risk factors that increase the cost of producing early blueberries in Florida.

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FRUIT FIRMNESS AND PECTINMETHYLESTERASE ACTIVITY DURING ON-TREE RIPENING OF PEACH

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Additional index words. Prunus persica, fruit softening, fruit ripening.

Abstract. Fruit firmness and pectinmethyltransferase (PME) activity were determined at 3 harvest dates over 2 weeks for 11 low chill and 5 high chill peach (Prunus persica) varieties of which 11 were melting flesh (mf) (excluding O’Henry) and 4 were non-melting flesh (nmf) varieties. Firmness decreased in all classes as fruit became more tree ripe. However, there was no apparent relationship between PME activity and major changes in firmness for low vs high chill, or mf vs nmf classes. Thus, on-tree initiation of ripening and softening in peach fruit was not related to PME activity. Levels of PME activity did not fully explain the softening differences between varieties. ‘O’Henry’ had a slower softening rate than mf varieties and lower PME activity than found at each harvest date in either mf or nmf varieties indicating that it has a different flesh type.

Materials and Methods

Fruit material. Eleven low chill (9 mf and 2 nmf), 4 high chill (2 mf and 2 nmf) and ‘O’Henry’ peaches were evaluated for mesocarp firmness and PME activity. Peach varieties were chosen to represent the range of firmness available in low chill and high chill, mf and nmf classes. Fruit were harvested from southern Queensland commercial orchards, the University of Queensland, Gatton Campus orchard, or the Queensland Horticulture Institute (QDPI), Stanthorpe orchard, between October 1996 and March 1997.

Preparation for biochemical analysis of tree ripened fruit. For each variety, 5 to 10 fruit were selected at 1) two weeks before maximum background color; 2) one week before maximum background color (ca. commercial harvest date) and 3) time of maximum background color. Background color (yellow, epicarp skin appearing with the red skin) has been a standard har-