ALABAMA A&M AND AUBURN UNIVERSITIES

ALABAMA COOPERATIVE Extension SYSTEM

ANR-1057A

Principles of Freeze Protection for Fruit Crops

Freezes in late winter or early spring can limit the successful annual harvest of most fruit crops in Alabama. Growers who understand certain weather terminology and available methods of freeze protection can better use forecasts and manage their operations for a consistent annual harvest. Managing freeze protection systems requires considerable time and experience. This publication is designed to help growers learn more about the dynamics of frosts and freezes that affect fruit crops.

Understanding Weather Terms Related to Freezes

Heat Transfer

Movement of heat is always from a warmer to a colder body. There are three basic forms of heat transfer: conduction, convection, and radiation.

Conduction is the transfer of heat through solid bodies or bodies in contact. Heat is transferred from molecule to molecule as it moves through the body. For example, heat movement through soil or a metal rod is conduction.

Convection is the transfer of heat through the movement of heated liquid or gas, such as air. For example, when a heater is operating in an orchard, cold air moves toward the heater, becomes warm, and rises upward. A form of forced convection occurs when a helicopter or wind machine is used to move air past a heater and mix the air in an orchard.

Radiation is the direct transfer of heat energy through space from one object to another. This is the form by which the earth receives the sun's energy. The sun's energy traveling through space creates heat as it strikes the earth's surface. Energy radiating from the soil surface and from plants is lost to space (as on clear nights) or is absorbed or reflected by water and water vapor (as in clouds). Radiation travels in straight lines only, which means that only those portions of plants that are in direct line with nearby heaters receive radiant heat. Very little heat is absorbed by dry air.

Temperature Inversion

During daylight hours, the radiant energy of the sun warms the earth's surface, including plants and soil. As plants and other objects warm, they in turn warm the air around them. The effect of this phenomenon is that layers of air near the earth's surface warm while much more elevated air in space remains cold. Thus, air temperature decreases with height above the surface during the day (outer space is very cold). However, during the night, solid objects such as plants and the soil lose heat to the sky by radiation. As the earth's surface cools, it cools the air around it. This results in a reversal of daytime conditions and is referred to as a temperature inversion because warmer air is now located above the cool air at the surface (Figure 1).

If a temperature inversion occurs, the greatest amount of warmer air is usually some 25 to 200 feet above the surface, although it may be several degrees warmer only 5 to 10 feet above the surface. The height of the warm air layer as well as the temperature differences that develop can vary from night to night as well as during a single night.

A strong inversion is one in which temperatures in the "inversion zone" are at least 7 to 10 degrees warmer than temperatures at the surface. However, measurements from remote weather stations in the state and from helicopters used for freeze protection have shown strong inversions of 6 to 8 degrees at 50 to 60 feet and 8 to 14 degrees at 100 to 200 feet. Strong inversions afford an excellent source of heat that helicopters

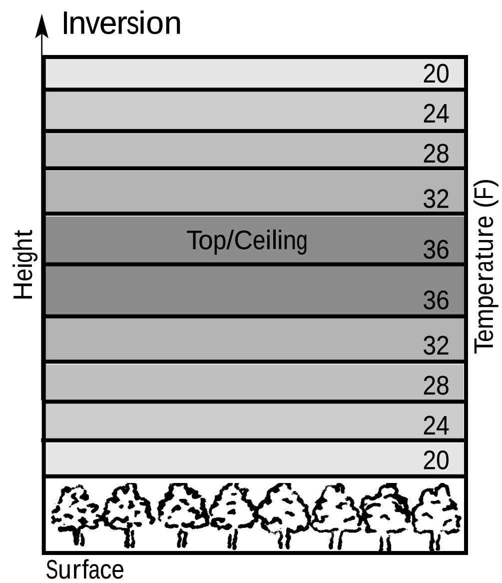

Figure 1. Temperature zonation during an inversion. Temperature increases with height to the ceiling and then decreases above it. Frost protection techniques use the warmer air above the orchard as a heat source. Used with permission. North Carolina Cooperative Extension Service Horticulture Information Leaflet 705-AS, 1994.

and wind machines can force downward to increase surface temperatures. Heating is also more effective when strong inversions occur. Small inversions of only 1 to 2 degrees do not afford enough heat to be used for effective freeze protection except in very marginal freezes.

On flat ground, an inversion that forms above 50 to 60 feet is not considered of real value because wind machines are unable to pull enough of the warmer air to the surface to make a temperature difference. However, helicopters can force warmer air downward from a 100- to 200-foot level.

More strongly sloping ground tends to give stronger inversions. And on sloping ground, even wind machines are able to move the warmer air downhill to warm lower areas. The warmer air aloft tends to reduce the upward movement of air warmed by heaters or irrigation. Without the warmer air above, the air warmed by heat or irrigation, being lighter than the surrounding colder air, will rise and continue to be lost from the orchard or field.

Differences between a Frost and a Freeze

The terms *frost* and *freeze* are often used interchangeably but refer to two different weather events. The term ***freeze*** is normally used to describe an invasion of a large, very cold air mass from Arctic or Canadian regions. This event is also called an advective or wind-borne freeze. Wind speeds during an **advective freeze** are usually greater than 5 mph. Clouds are commonly present during much or all of the event, and air is usually quite dry (low dew points). Freeze protection systems are usually of limited value during this type of severe freeze.

A **radiational frost** (also called a **radiational freeze**) typically occurs when winds are calm (usually 0 to 3 mph) and skies are clear. Under such conditions, an inversion may form because of rapid radiational cooling at the surface. If a strong inversion forms, temperatures aloft (usually up to 100 to 200 feet) may increase 10 degrees or more above surface temperatures.

Most people think of frosts as frozen moisture on plant surfaces. However, there are two types of frosts: a white frost and a hoar, or black, frost. Visible frost occurs when atmospheric moisture freezes (forms small crystals) on plant and other surfaces. Dew (free water) forms when the air temperature equals or drops below the dew-point temperature. As temperatures continue dropping on cold nights, this dew may freeze or form frost by sunrise. Because of radiational cooling of surfaces, frost may develop on rocks, plastic, leaves, and other surfaces while air temperature is still above freezing (32°F). If the air temperature is below the freezing point of water (32°F) when water vapor is lost from the air, ice crystals, rather than dew, form, and the frost is called **white frost**. The temperature at which this occurs is referred to as the frost point.

When the dew-point temperature is below the freezing temperature of the air, neither frost nor dew forms. Such a condition is referred to as a **black frost**. The development of frost depends on the dew point or frost point of the air. And the drier the air, the lower the dew point.

Damaging frosts seldom occur in Alabama through slow, seasonal lowering of air temperatures. The most common freeze event scenario is for a blast of Arctic or Canadian air to move rapidly southward across the state. The first night or two of the event usually features strong winds, clouds, and rain followed by clearing skies and the continued importation of very cold, dry air. Thus, advective or wind-borne freezes are common the first one or two nights. With continued clearing skies, the next night or two usually feature radiational frosts (or freezes) and the coldest temperatures.

Temperature and Humidity Measurements

Several temperature and humidity measurements are valuable to growers during freeze events. These measurements include relative humidity, air temperature, wet bulb temperature, and dew-point temperature.

Relative humidity is commonly given by radio and TV announcers as a percentage from 0 to 100. It is a measure of how much water vapor the air can actually hold at a given temperature. A relative humidity of 100 percent means that the air is fully saturated with water vapor at the reported temperature. The relative humidity changes quite rapidly as the temperature changes, although the water vapor content (referred to as vapor pressure) changes very little over a 24-hour period. And because the relative humidity changes with changing temperatures, it is not a useful method for monitoring the moisture content of an air mass.

Air temperature, which is so important during the freeze events of fall, winter, and spring, can also be referred to as dry bulb temperature. Official temperatures recorded by the National Weather Service (NWS) are taken at a 5-foot elevation above the soil surface. When the NWS forecasts a frost or freeze, the temperatures used are for air temperature (dry bulb) at a 5-foot elevation. This is important to remember because on calm, clear nights, actual air temperature at the soil surface or on crop beds (such as strawberries) may easily be several degrees colder than it is at a height of 5 feet.

Wet bulb and **dew-point temperatures** are also measurements that are valuable to growers during freeze events. Wet bulb temperature is a measurement of the evaporative cooling power of the air and can be measured using a sling psychrometer, an instrument comprised of two thermometers. The wet bulb thermometer has a gauze wick attached to the bulb end. To measure wet bulb temperature, the gauze wick is immersed in water, and the instrument is swung in a circular motion for a few minutes. Moisture being removed from the gauze wick by evaporation causes a cooling effect and lowers the temperature of the bulb. The lower the moisture in the air, the lower the temperature of the bulb will drop. The amount of the temperature drop is proportional to the rate of evaporation, which has a functional relationship to relative humidity and air (dry bulb) temperature. The two readings can be used to determine the dew point from a psychrometric table.

Measurements of wet bulb and dry bulb temperatures can be used to determine relative humidity from conversion tables. Wet bulb temperature is often computed by the NWS, using other measurements.

Knowing the wet bulb temperature is especially important to growers who use irrigation for freeze protection, as with strawberries. Growers use wet bulb temperatures (or estimates thereof) to determine when to turn irrigation systems on and off. Wet bulb temperature is a useful measurement because it is the lowest temperature to which plant tissue will fall when water is first turned on, when insufficient water is being used, or when power or mechanical failure causes the irrigation system to shut down too early. Except under conditions in which the air is saturated with moisture, the wet bulb temperature is normally lower than the air temperature but higher than the dew-point temperature.

Dew-point temperature is defined as the temperature at which moisture condenses out of the air. The dew point is considered the theoretical low that air temperature can drop to at any time. Although forecasters do not normally include dew-point temperatures, they can easily be determined for the same hour if the air temperature and relative humidity are known. Warmer air holds more moisture than cold air holds. When the dew point is high, the drop in temperature is much more gradual on a cold night. However, imported Arctic or Canadian air is usually quite dry and is characterized by low dew points. During some freeze events in the state, it is not uncommon for dew points to fall to zero or below.

Because the water vapor content of an air mass generally changes very slowly, dew point serves as a good indicator of how dry or moist the air is. Air is comprised of a mixture of gases—mainly nitrogen, oxygen, and argon. Water vapor constitutes only a fraction of 1 percent of the gases in the atmosphere but is the single-most-important absorber of heat radiated from the earth's surface. Consequently, the amount of water vapor in the air significantly affects the rate at which heat is lost during a typical radiational freeze night.

Windy, advective freezes with low dew points can desiccate peach and nectarine flower buds even when the buds are dormant. Growers should use dew-point information in planning for and carrying out freeze protection activities because low dew points allow a rapid drop in temperature during radiational frost/freeze events.

Understanding Microclimates

When it comes to temperatures, not all farming sites are equal, even when they are located in the same general area. When temperature differences occur in rather small areas, these areas are commonly referred to as **microclimates**. Microclimates are either associated with the natural topography of the area, caused by man-made structures, or developed from farming practices. Microclimates may also be caused by a combination of all three. Small microclimates may include only portions of one farm, while larger microclimates may include an entire county. An example of the latter is the Brewton area, which is in extreme south Alabama. Because of natural cold air drainage, this area is often as cold or colder than areas 200 miles north of it.

Effects of Natural Terrain and Topography

During cold nights, temperature differences are quite common in hilly areas. On radiational frost nights, as air near the surface is cooled, it becomes more dense and flows downhill to lower areas where it collects. These areas will become much colder than those higher in the terrain. These locations are commonly called **frost pockets** or **cold pockets.** Dense stands of timber and other plant growth may slow or block movement of cold air, resulting in a **cold air dam**. Such obstructions create the same blockage effect if they are located anywhere along areas where cold air is draining downhill—for example, near the bottom or the top of the slopes.

During advective (windy) freeze events in winter or early spring, the winds are predominately from the north/northwest. Consequently, a natural windbreak of tall pines or hardwoods on the north and northwest sides of an orchard is highly desirable. The value of such windbreaks in reducing damage to fruit buds and flowers of crops such as peaches has been demonstrated in portions of central and north Alabama. If windbreaks are used to modify windy conditions, special attention must be given to the creation of cold air dams that could cause cold pockets. Cold air pockets can be minimized by opening up portions of the lower several feet of windbreaks to allow cold, dense air to move through. For obvious reasons, the ideal place to have a windbreak is on top of a hill where it can provide maximum benefit in breaking the wind while not impeding movement of cold air downhill.

Bodies of water such as lakes are quite helpful in modifying temperatures and reducing crop damage, especially when located on the north and northwest sides of orchards. The Great Lakes are well known for helping protect fruits grown along the southwest coastal area of Michigan. The many individual lakes scattered across portions of central Florida are also well known for reducing freeze damage to citrus grown in those locations. Even rather small bodies of water from 1 to 10 acres can reduce freeze damage in peaches and other crops during radiational frosts/freezes when located very close to the crop on the north and northwest sides of plantings.

Highly elevated, windy locations are usually best. Within a given area of a farming region, the most-elevated sites tend to be the warmest during freeze events. For example, if a county has areas where elevations range from 400 to 800 feet above sea level, those sites with 700- to 800-foot elevations are almost always the warmest during freezes. Because these sites are the most elevated in an area, they also tend to be the most windy. Experienced growers realize the value of such windy sites because the sites tend to be warmer on radiational freeze nights when other less-elevated locations become quite calm and colder much quicker. What is so amazing is that even very light winds of only 2 to 4 mph, which are much more persevering on elevated sites, can keep temperatures several degrees warmer than temperatures on less-elevated locations.

South slopes are valuable. Most horticultural publications about fruit orchards indicate that northern slopes are preferred over southern slopes. They say that trees planted on the northern slopes tend to remain dormant a few days longer and therefore are more likely to escape freezes. However, most of these publications are describing orchards in more northern states.

In Alabama, stone fruit orchards (such as peaches) located on the southern slopes of highly elevated areas tend to escape freeze damage much better than similar blocks of trees located on northern slopes do. The primary reason for this difference is that the time of budbreak does not vary greatly between slopes, and the trees on northern slopes are damaged much more severely by the extremely cold and dry winds during advective winter or spring freeze events. In many cases, dormant as well as active buds are literally desiccated by the strong, dry winds that generally occur during the first night or two of major freeze events.

Effects of Soil Types

Soil characteristics can have a microclimatic effect. Growers have found that in late winter, orchards may become active slightly sooner on heavier, clay-type soils and/or darker-colored soils (such as reds and blacks) than they do on lighter-colored, sandy soils. Although lighter, sandy soils tend to warm faster, they reflect more heat during the day (trap less heat) and lose it faster during the night than darker, heavier soils do. This effect is somewhat like the earlier flowering and cropping of plasticulture strawberries because of warmer soil temperatures. However, if the orchard floor is allowed to become covered with grass and other vegetation, the differences among soil types become minimal.

Effects of Cultural Practices—Orchard Floor Management

One of the greatest impacts a grower can have on creating microclimatic effects through cultural practices is management of the orchard floor. The condition in which the orchard floor is maintained can increase or reduce minimum temperatures during radiational frosts/freezes by several degrees. On freeze nights, this amount of change may be sufficient to be the difference between keeping a crop and losing it.

In tree fruit as well as small fruit plantings, keeping the area beneath plants free of vegetation so that the majority of the soil surface is exposed to the sun is highly advantageous. This practice allows the maximum amount of radiant energy to be stored in the soil during the day. To absorb this energy most efficiently, the soil must be firm and moist. During a freeze event when radiational cooling occurs at night, the long-wave radiation being lost from the soil surface moves upward through the plants, providing a warming effect to the crop and the surrounding air. This warming effect may easily increase the temperature in a planting by 1 to 3 degrees during a calm radiational frost/freeze situation.

If the orchard floor is mostly covered with a cover crop or other plants, the soil will store less heat because the ground cover will reflect radiation and transpire to cool itself during the day. Recent work in Florida where high-density pine bark growing systems are being used with blueberries has shown that such plantings become 4 degrees colder than similar unmulched plantings do. Thus, dead or live plant material that creates a mulching effect (traps heat in the soil) develops a cold microclimate.

It is a common practice for orchards to be maintained with a weed-free strip 2 to 6 feet wide (depending on the age and type of crop) on either side of the plant row. The orchard middle is usually maintained with natural or planted sod for ease of movement of equipment and for erosion control. Mowing the orchard floor grass to 2 inches or lower before freeze problems develop can add warmth to the orchard through daily heating of the soil and release of heat at night. A weed-free, firm soil with good moisture content is the most efficient way to provide natural warmth to a fruit planting on a cold night. Soil should never be cultivated just before a freeze.

Effects of Man-Made Topographical Features

There are several other factors growers have little control over but which can have varying effects on freeze protection. Growers in north Alabama have been the beneficiaries of extra warmth on freeze nights because cotton land adjacent to orchards is tilled in late winter or early spring for May plantings. Large areas of clean, firm soil, full of moisture from winter rains, provide somewhat of a "lake effect" by releasing substantial heat that may drift across orchards during freeze nights. Airline pilots will attest to the tremendous jetties of heat released into the atmosphere from large areas of freshly tilled farmland versus the much calmer skies located above areas covered by plants. When these recently cultivated but firm and wet areas are located on the north and northwest sides of orchards, a small but sometimes beneficial effect may be realized during freezes.

Large areas of paved roads, such as interstate highways, release substantial heat on cold nights, and this combined with heat released by vehicles and air currents created by traffic can sometimes provide a beneficial effect to several rows of trees located close to such highways. This has been experienced in some states during the past 20 years.

Weather Forecasts

For a long time, the NWS provided Alabama, as well as much of the rest of the United States, with specific agricultural forecasts. However, in April 1996, the NWS closed all of its agricultural weather service centers. As a result, growers who want specific agricultural weather information must now subscribe to one of two private agricultural weather firms, one located in Auburn, Alabama, and the other in the Northeast. Some growers have contracted with private meteorologists for weather information.

The NWS continues providing forecasts similar to what they provided in past years, but this information is general and is not intended for direct agricultural application. The NWS Birmingham office serves most of Alabama, and the Mobile office serves several southwestern counties. Weather information from the NWS can be obtained from NOAA radio, special bulletins on TV and radio, newspapers, and the Internet. General weather forecasts and current conditions are always available through TV and Internet links provided by special weather channels and local TV stations.

Frost/freeze warnings are issued by the NWS according to forecast conditions. Table 1 gives an explanation of how the wording of these warnings should be interpreted. The type of warning given will help growers understand which, if any, freeze protection methods may be effective. For example, a freeze warning implies that winds may be too high for successful use of helicopters, wind machines, or overhead irrigation.

Agricultural weather information is now available only via the Internet through private firms on a fee basis. Currently, weather information is being obtained from 17 remote weather stations located strategically throughout Alabama (see Table 2). This network of remote weather stations was created and formerly managed by the Alabama Cooperative Extension System and the NWS. The network is now being maintained through an agreement between Auburn University and a private agricultural weather firm. Weather information is available for the preceding 24 hours (ending 7 A.M. each morning) and the last 30 days through the Internet and internal university network. Weather information from this network is provided free to users.

Efforts are being made to enable growers to access real-time information from the remote

Table 1. Explanation of Frost/Freeze Warnings Given by the NWS

Warning	Air Temperature	Wind Speed
Frost	Above 32°F	Below 10 mph
Frost/Freeze	Below 32°F	Below 10 mph
Freeze	Below 32°F	Above 10 mph

Table 2. Network Locations of Automated Remote Weather Stations in Alabama*

Name of station	Physical location Geographical location	lat.	lon.	elev.
South Alabama				
Grand Bay	Mobile County, 5 miles NW of Grand Bay	30.52	88.28	110
Fairhope	Baldwin County, at Gulf Coast Substation off AL 105 in Fairhope	30.55	87.88	230
Semmes	Mobile County, beside US 98 at Mary Washington High School in Semmes	30.70	88.25	210
Brewton	Escambia County, at Brewton Experiment Field about 4 miles northeast of downtown Brewton, about 3 miles off US 31	31.14	87.05	160
Headland	Henry County, beside US 31 at Wiregrass Substation in Headland	31.58	85.39	370
Union Springs	Bullock County at Turnipseed; Ikenberry Place Substation 6 miles east of Union Springs	32.15	85.65	440
Central Alabama				
Marion Junction	Dallas County, at Black Belt Substation near Marion Junction off US 80 onto County Road 45	32.47	87.22	200
Milstead	Macon County, at E.V. Smith Research Center 1 mile north of I-85 near Shorter	32.45	85.88	251
Auburn	Lee County, on old agronomy farm 1 mile east of Auburn University main campus, beside US 29	32.60	85.50	652
Prattville	Autauga County, at Prattville Experiment Field on County Rd. 4, off US 31, 4 miles south of Prattville	32.43	86.45	200
Thorsby	Chilton County, 50 yards from Chilton Area Horticulture Substation Hdqrs. beside County Road 29 (4 miles west of I-65)	32.92	86.67	680
North Alabama				
Cullman	Cullman County, at North Alabama Horticultural Substation, 4 miles east of I-65	34.18	86.85	800
Oneonta	Blount County, on private property 1.5 miles down County Road 33 off U.S. 231 from Oneonta	33.98	86.52	870
Belle Mina	Limestone County, at Tennessee Valley Regional Extension Center located 2 miles north of Belle Mina (1½ miles east of I-65)	34.70	86.88	600
Sand Mountain	Dekalb County, at Regional Research and Extension Center east on AL Hwy 68 about 2 miles from Crossville	34.28	85.97	1195
Ider	Dekalb County, located in Ider near city hall	34.70	85.67	1000
Hazel Green	Madison County, on agricultural research farm of Alabama A&M University, beside US 431, 3 miles north of Meridianville	34.97	86.50	850

*All remote weather stations are Campbell Scientific CR-10 units.

weather stations as could be done previously via the Internet or bulletin board. A voice modem that provides real-time information for growers is currently being operated at one of the remote weather stations.

Forecasts by the NWS are generally based on temperatures of warmer, urban areas. Many of the locations are airports, where temperatures are almost always warmer than those in surrounding areas. During freeze events, rural farm areas often experience temperatures that are 3 to 6 degrees colder than forecasts predicted. In some cases, the very coldest locations in an area may be as much as 8 to 10 degrees colder than those forecast. It is also possible to have frosts in rural areas when the temperatures forecast for urban areas are in the mid- to high 30s with no frost.

No matter who is issuing forecasts, growers should rely on the updated, latest forecast for the freeze event. In addition, growers should remember that forecasts are based on temperatures taken at the 5-foot height. On calm nights, temperatures at the soil surface may be several degrees lower than temperatures at the 5-foot height. This is especially important to know when managing crops that are located at the soil surface, such as strawberries.

Monitoring Freeze Conditions and Maintaining Weather History

Alabama is presently divided into ten forecast zones. Each zone is an area made up of several counties that possess similar features, so relative weather conditions do not differ greatly across the entire zone. However, within each zone are microclimates, resulting in considerable differences in minimum temperatures that may be attained during a freeze event.

Because of the effects of microclimates, growers must carefully monitor how major freeze events affect their farms. Growers should keep records that include the temperatures throughout the duration of the freeze at numerous locations across the farming area. Records of the occurrence of frosts, cloud cover, wind speed, dew point, and wet bulb temperatures are also helpful. Notes should also be kept on the condition of the orchard floor, when and if freeze protection methods were used, stage of crop development, variety and block identity, and extent of freeze damage. These records should be placed in a farm weather file along with copies of the forecast conditions for the same freeze events.

Maintaining a weather history over time has several benefits for a grower. Over time, these records will allow growers to carefully compare temperatures and other weather measurements with those from the nearest forecast sites. Once orchards or plantings are identified as being in warmer or colder sites on the farm, growers can make better management decisions regarding the best use of weather protection systems.

Maintaining weather records can also help a grower when planning a fruit orchard. Under ideal conditions, a grower should maintain a winter/spring temperature record (recording the minimum temperatures) of potential new sites for future plantings. These records should be maintained for a minimum of 1 to 3 years in order to compare these locations to existing orchards and thereby determine if one or more of these should be avoided because of extremely cold minimum temperatures.

Monitoring Air Temperature

Growers who want very specific information about one or more sites can set up an inexpensive temperature-monitoring station. Growers can use temperature data from a field station to determine when a variety that has a particular chilling requirement (such as an 850-hour selection) will have its rest requirement satisfied. Growers can also determine heat units—commonly referred to as growing degree hours (GDHs)—and make a fairly accurate prediction of 50 percent bloom date. This information can also help growers determine if a variety that has a given chilling requirement would tend to flower too early to be used in a particular location. Obviously, most growers do not go to this much trouble in examining a future site, but the potential for doing so exists.

To properly monitor the temperature conditions in a fruit planting, growers can place several minimum/maximum thermometers in inexpensive wood shelters (for measurements at 5-foot height) arranged across an area. These thermometers indicate the highest and lowest temperatures reached during any period. Normally warm, cold, and intermediate sites should be included. One thermometer every 5 acres may be adequate, but more or fewer could be used based on terrain differences and the numbers of cold pockets. Even small changes in elevation such as 2 to 3 feet in a 5- to 10-acre planting can create cold pockets.

Some growers prefer to hang thermometers from branches of plants, but the readings can be misleading if air temperature measurements are being used to manage freeze control systems. Exposed thermometers may read several degrees lower than actual air temperature on clear, calm nights.

During freeze events, helicopters can be effectively used to monitor the temperatures of inversion layers and their heights above the surface. Steadily measuring temperatures on orchard sites at least every 30 minutes can help a grower make decisions about where and when protection is needed. Radios can be used to tell helicopter operators which blocks require protection at any given time.

Monitoring Plant Tissue Temperature

Today, there are systems that can electronically monitor plant tissue (leaves and fruit) during a freeze, using thermocouples. Thermocouples are fairly inexpensive, easy-to-use devices for measuring temperature. They are inserted into buds, flowers, and fruit. This type system can give a very accurate picture of the severity of the freeze as the night progresses.

Most growers, however, do not use crop temperature measurements to manage freeze protection. One of the primary problems is that an index of threshold temperatures for various plant parts is not currently available, although considerable research has been done. For example, citrus has been carefully studied, and it is well established that 21.5°F is the average freezing temperature for leaves. Therefore, to prevent damage, leaf temperature should never be allowed to drop below 22°F. In the case of stone fruit and small fruit, however, similar threshold temperatures are not readily available for all stages of bud, flower, and fruit development.

Another problem with using tissue temperatures is the fact that in some situations, floral parts as well as ripe fruits have the ability to supercool (drop below their normal freezing points) and not freeze. And whether fruits will supercool during a given freeze is not easy to determine.

Furthermore, the temperature at which plant tissue freezes is affected by the presence of moisture on the plant surface. Dry plant tissue freezes at lower temperatures than wet plant tissue does. Work in California has shown that citrus fruit that are covered with ice are cooled much more rapidly than dry fruit are during radiational freezes (snow does not provide as much cooling effect).

Finally, studies show that the freezing point for fruit buds and other floral stages changes as these tissues acclimate and deacclimate to changing temperatures. Cold temperatures in the winter cause fruit plants, including fruit buds, to gain cold hardiness (freeze at lower temperatures), while deacclimation (loss of hardiness) occurs with warmer temperatures. Fruit buds regain hardiness in response to colder temperatures several times slower than they lose hardiness as a result of warmer temperatures. Fruit buds and flowers that develop slowly during colder temperatures are usually able to withstand lower temperatures during a freeze than are similar plant tissues that are growing rapidly during warm conditions.

A system has been developed in Washington for taking shoot samples from orchards during the winter and examining the buds to determine the threshold temperatures for freeze damage. This information can then be used to decide on the use of freeze protection. This method is not currently being used in the Southeast.

Because of the uncertainties about when different plant tissues freeze under varying freeze conditions, growers will probably continue to use air temperature measurements to decide if protection is needed.

For information about freeze protection methods, see Extension publication ANR-1057B, "Methods of Freeze Protection for Fruit Crops."

Acknowledgments

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ALABAMA COOPERATIVE **Extension** SYSTEM

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Arlie A. Powell, *Extension Horticulturist,* Professor, and **David G. Himelrick,** *Extension Horticulturist,* Professor, both in Horticulture at Auburn University

For more information, call your county Extension office. Look in your telephone directory under your county's name to find the number.

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