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Protecting Landscapes and Horticultural Crops from Frosts and Freezes

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Figure 1. Kale drooping and water soaked from freeze injury.

Fall, winter, and spring bring the danger of frosts and freezes to Texas gardens, orchards, and landscapes. Although sporadic and unpredictable, these cold spells have left their mark on horticulture in Texas by wiping out peach crops, freezing pecans in their shucks, forcing the replanting of spring vegetables, killing valuable landscape plants, and necessitating the replacement of beloved avocado, citrus, and fig trees.

Home gardeners and commercial growers can minimize these losses by understanding how cold affects plants and implementing diverse strategies to protect them.

Plant freezing and hardiness

When the water inside plant cells freezes, ice crystals form that can pierce and damage the cell walls, killing the cells. As temperatures rise, fluids leak out of those cells and they begin to decay.

Freeze damage first appears as dark, water-soaked tissues (Fig. 1) that later turn brown or black and dry up (Fig. 2).

Many ornamental and edible plants have mechanisms to resist freeze damage. Trees and woody plants that go dormant, such as pecan and peach, can tolerate very low winter temperatures. However, they can be injured if they are too slow to stop growth in the fall or begin growing too quickly in the spring. Many species of woody evergreens, such as hollies, can tolerate tremendous cold.

Subtropical plants such as citrus and palms have variable levels of cold hardiness; some can withstand mild to moderate subfreezing temperatures. Their survival depends on their age, condition, size, and genetic mechanisms for acclimation (gain in the ability to withstand freezing) and the depth and duration of the cold.

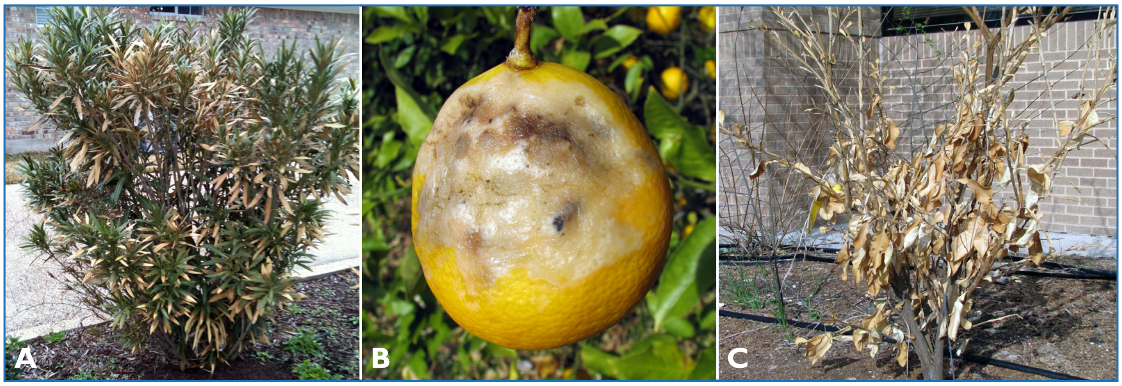

Figure 2. Freeze damage to **a)** a dwarf oleander, **b)** a Meyer lemon fruit, and **c)** a grapefruit tree.

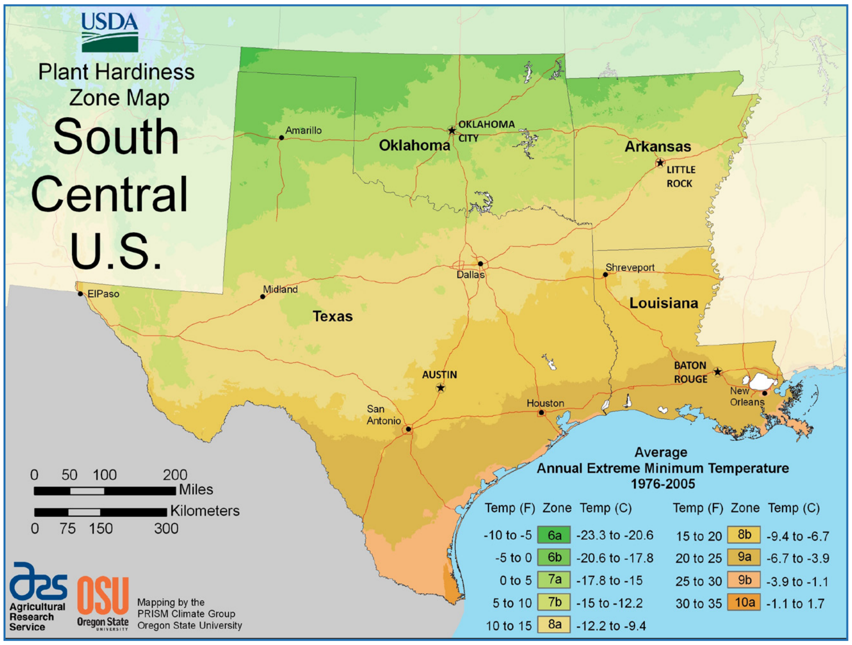

Figure 3. Plant hardiness map for the south-central United States (Source: U.S. Department of Agriculture).

Some species of herbaceous (non-woody) plants are cold tolerant, enduring all but the most severe cold in Texas. Examples are perennials like lilies and irises and annuals like violas and sweet alyssum. However, many spring- and summer-growing annuals and perennials may be damaged at, near, or even above freezing (32°F).

Likewise, most fruit and vegetable structures have little resistance to freezing temperatures, prompting a quick harvest when the forecast calls for frost.

Expected low winter temperatures for Texas are shown in the Plant Hardiness Zone Map (Fig. 3) of the U.S. Department of Agriculture. Plants are commonly rated for their ability to survive particular hardiness zones in gardening books, plant encyclopedias, and websites (example: https://aggie-horticulture.tamu.edu/ornamentals/natives/). For best results, select plants that will survive in your zone or lower numbered (colder) zones than yours.

Because Texas weather is often erratic, these guides do not always predict plant performance in freezes exactly. They also cannot account for a particular farm or landscape being colder or warmer than its surroundings because of its topography, urban microclimate, nearness to bodies of water, etc.

Many county Extension offices maintain plant recommendation lists and local planting dates for spring and fall vegetables, based on Table 1.

Plants can generally acclimate to freezing weather when they are exposed to consistent, gradually colder weather. Intermittent warm periods, not uncommon in Texas, can cause the plants to deacclimate, leaving them more vulnerable to damage in a frost or freeze.

To help plants withstand frosts and freezes, do not fertilize with nitrogen or harshly prune them in late summer, which will stimulate growth and make them less winter hardy.

Table 1. Latest spring and earliest fall dates with a 50 percent chance of a low temperature of 32°F. (Source: *National Oceanic and Atmospheric Administration* (NOAA) National Climate Data Center, courtesy of the Office of the Texas State Climatologist, 2013)

Location	Spring latest 32°F	Fall earliest 32°F
Abilene	24-Mar	12-Nov
Amarillo	15-Apr	24-Oct
Arlington	11-Mar	23-Nov
Austin	16-Mar	16-Nov
Beaumont	21-Feb	6-Dec
College Station	26-Feb	2-Dec
El Paso	17-Mar	14-Nov
Fort Stockton	17-Mar	18-Nov
Fredericksburg	26-Mar	9-Nov
Galveston	3-Feb	28-Dec
Houston	12-Feb	9-Dec
La Grange	8-Mar	24-Nov
McKinney	28-Mar	7-Nov
Midland	27-Mar	12-Nov
Nacogdoches	19-Mar	16-Nov
San Antonio	1-Mar	1-Dec
Stephenville	27-Mar	11-Nov
Tyler	14-Mar	19-Nov
Uvalde	1-Mar	28-Nov
Waco	13-Mar	21-Nov
Weslaco	18-Jan	28-Dec
Wichita Falls	28-Mar	10-Nov

Understanding frosts and freezes

Two types of cold events can damage plants in Texas: advective freezes ("freezes") and radiative frosts ("frosts").

Texans are familiar with the term *blue norther,* a windy cold front that moves south from Canada through the Great Plains. The technical term for these events is advective freezes.

Advective freezes bring sudden, steep plunges in temperature, wind speeds of more than 4 mph, and masses of cold air from 500 to 5,000 feet deep. They may bring clouds and precipitation at the onset and can take 1 to 3 days to make their way out of Texas.

These freezes create uniformly cold temperatures throughout the plant canopy, sometimes damaging the plants from their lowest to highest points. The harm is caused by low temperatures and drying, sometimes relentless, winds.

Some of the most serious plant-damaging cold events recorded in Texas have been advective freezes. Most frequent in the winter, they occasionally wreak havoc in the fall as they usher in winter suddenly before the plants have time to acclimate. Freezes generally become less numerous and less severe as spring arrives, although it takes only one serious freeze late in the spring to damage tender transplants and spring-blooming fruits.

Radiative frosts occur when the sky is clear and winds are less than 4 mph. During the day, the sun's radiation heats the plants and soil; at night, they lose radiation back to the sky. Plants and other objects cool faster when skies are clear because of the unimpeded loss of radiaion.

Depending on the amount of radiation that the plants gain during the day, they may cool steadily at night to the freezing point before sunrise. This can occur on clear-sky nights in the winter, spring, or fall. On cloudy nights, the clouds reflect radiation back toward earth, which slows plant cooling and reduces frost injury.

The most severe radiative frosts occur when the weather is cloudy during the day and clear at night. The clouds reduce the amount of radiation absorbed during the day; if they dissipate late in the day or early during the night, intense cooling and plant freezing may be experienced.

Because the tops of the plants are most exposed to the open sky, they are the likeliest parts to be injured by radiative frost. The leaves at the top of the plant slow the radiation loss from the lower sections, so the cold damages the plant's outer and upper parts most on frost nights.

Under radiative conditions, the leaves, stems, and other plant structures that have full sky exposure can be as much as 5 degrees colder than the recorded air temperature. This is why some plants show frost injury even when the recorded air temperatures did not drop below 32°F.

Radiative frosts are accompanied by temperature inversions, which occur when the ground cools quickly but no wind mixes the air, leaving layers of cold air close to the ground. Depending on the topography and inversion strength, a cold air inversion may be 50 to 150 feet deep.

Low-lying topography is colder in radiative frosts because of the inversion and the tendency for cold air, which is heavier than warm air, to settle into "frost pockets." Avoid planting cold-sensitive plants in frost pockets. Monitor the temperature near the ground, which can be a few degrees colder in a radiative inversion.

Radiative frosts occur often in winter and can seriously damage delicate and marginally adapted plants. They generally occur one or more nights after an advective freeze has left the region. Although fewer frosts occur in the spring, they are the ones chiefly responsible for damage to spring-blooming fruit crops or early-spring vegetable transplants.

Although a radiative frost does not last long—as little as 1 to 4 hours—the damage can be disastrous.

Dew point and frost

The dew point is the temperature at which the air releases moisture. It is a function of temperature and relative humidity.

When the dew point is above freezing, it leaves evidence in the form of fog in the air or dew on the ground. At night, the ground, rooftops, automobiles, and plant parts cool (from radiation loss) to the dew point, produce condensation or dew, and then may continue to cool to the freezing point or lower. The dew then crystallizes into frost.

Frost may or may not indicate serious plant injury. Frost that forms only briefly before sunrise may be of little consequence; however, a thick frost on a strong radiative night may mean serious plant injury.

Frost rarely develops on plants during advective freezes. The arctic air has low relative humidity, and dew points are often well below 32°F. Under these conditions, the plant cells may freeze but no frost forms on the surface. This condition is also known as a *black frost.*

Growers of high-value crops that are susceptible to frost should check weather forecasts for the nightly dew point. The dew point is considered the "basement" or low temperature for the night because the condensation of moisture or formation of ice slows or halts the rate of temperature drop.

If the dew point is above freezing, most plants are unlikely to be injured by frost. But a sub-freezing dewpoint signals the need to consider protective measures.

Forecasts and temperature measurement

Several tools can help gardeners and commercial growers forecast and measure the effects of frosts and freezes. These tools include weather websites and apps, recording thermometers, and sling psychrometers.

Websites and apps: Free and fee-based weather websites and mobile apps can provide detailed 5- to 10-day forecasts, including predictions of precipitation, dew points, wind speeds, and hourly temperatures. Forecasts can help gardeners and growers determine whether the conditions will be advective, radiative, or a combination of both, and thus what protective measures to take.

Recording thermometer: Accurate recording thermometers can help growers know when they need to start and stop taking protective measures. Simple high-low recording thermometers or temperature dataloggers that interface with computers are economical and readily available.

To measure the air temperature accurately and compare it to other local sites, place the thermometer or datalogger under branches, leaves, or other vented cover. Radiative cooling may otherwise skew the measurements.

Sling psychrometer: If you plan to use water to protect plants from cold, it is important to know the *wet bulb* temperature, which is always lower than the dry bulb (non-wetted air) temperature (except when relative humidity is 100 percent). Use a wet bulb thermometer or a sling psychrometer (Fig. 4) to determine what the plant temperature will be if the plant is misted with water.

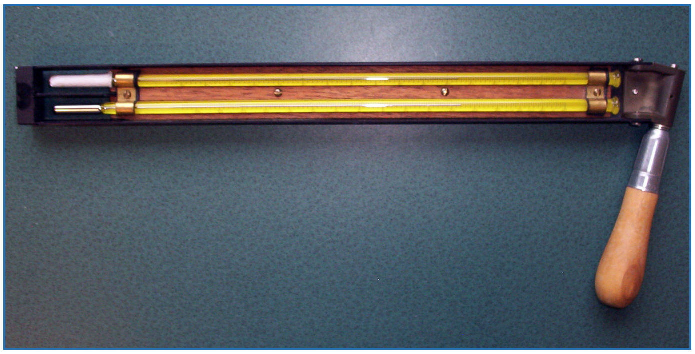

Figure 4. A psychrometer.

Protection from radiative frosts

Methods that can help protect plants in a radiative frost include using covers, planting near buildings, watering the soil, placing containers of water near the plants, and running wind machines.

Anything that reflects radiant energy downward will slow the cooling of plants during a radiative frost. For example, you may have noticed frost on the parts of your lawn or car windshield that are exposed to the sky but not on the parts under a tree canopy—regardless of whether the trees have leaves or bare limbs. The canopy slows cooling.

Covers: An effective protection for radiative frosts is to cover the plants with sheets, blankets, or commercial spun-bound polyester frost-blanket materials, also called row covers (Fig. 5). Frost blankets are available with increasing density, and the heavier fabrics protect best. In a severe frost, consider covering sensitive plants with two layers of frost blanket.

Covers are used not to provide insulation in a frost, but to slow the plant's cooling caused by the clear sky. Drape the cover loosely over the top of the plants and either allow it to hang widely or stake it outward at the corners tent-style. The cover will trap the radiant energy rising from the ground around the plants that need protection.

Figure 5. A spun-bound polyester frost blanket, also called a row cover.

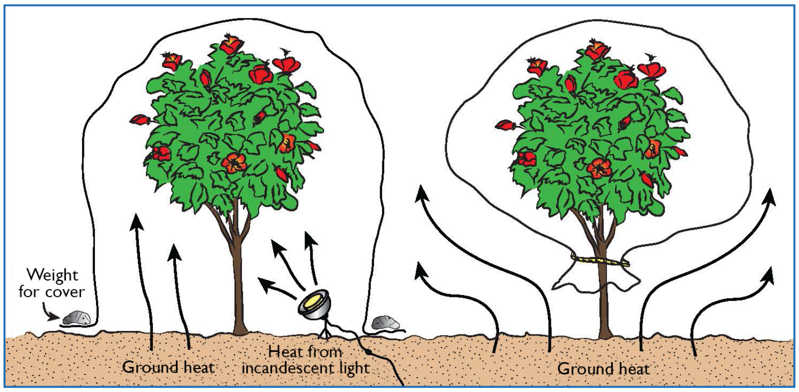

Figure 6. Proper plant cover loosely draped over the top of a plant (left), and an improperly placed cover tied tightly around the trunk (right).

For nights when a frost is forecast, wait until late in the afternoon or evening (before sundown) to put the row covers or blankets in place; the timing will enable the soil and plant tissues to gain the maximum amount of radiation.

Bare soil captures more solar radiation during the day than soil covered by grass or other ground covers.

Because only low winds accompany most frosts, the covers will need little tying or securing. Avoid creating "landscape lollipops" by tying the blankets around the trunk tightly, which reduces the amount of ground radiation that the cover can capture (Fig. 6).

Other good covers for plants include cardboard boxes and large garbage cans.

During a radiative frost, be aware that clear polyethylene (plastic) sheeting or greenhouse film is not the best material to drape or cover plants; its fast rate of radiant cooling can cause damage at the point of plant contact. Opaque or white films reflect radiant energy downward better than do clear films; they also won't overheat plants as easily if the cover is inadvertently left in place on a warm, sunny day.

Figure 7. Citrus planted under pine trees for protection from radiative frost damage.

Other covers: Another way to reduce radiative cooling on a clear night is to place cold-sensitive annuals or subtropicals under taller trees or even roof overhangs. Some citrus growers have avoided radiative frost damage by planting under pine trees (Fig. 7). Although the pines reduce the sunlight intensity and the number of citrus blossoms, they provide a permanent and effective frost-protection cover.

Buildings: Buildings, especially those made of stone and concrete, collect radiation during the day and release it at night. In radiative frosts, the plants growing along or near the southern/southwestern exposed sides of rock walls or buildings may have a slight temperature advantage.

Watered soil: The day before a frost night is expected, water the ground and soil liberally around frost-susceptible plants. The wet soil and water puddles will capture radiant energy during the day and release it upward and around the plants during the night. Further, water gives off heat as it freezes, providing more warmth for the plants nearby.

Watering the soil around plants before a frost or freeze also benefits the plants directly, enabling them to resist the freezing process better if they are not also experiencing drought stress.

Containers of water: Water cools more slowly than air. Water collected in barrels, buckets, or other storage containers can help keep plants from frost injury. Placed near plants during the day and put under a cover with the plant at night, the containers of water will give off small amounts of heat as they cool.

A gallon of water releases about 8 BTUs of heat for each 1-degree reduction in temperature. A 55-gallon barrel dropping 10°F will give off 4,400 BTUs during its cooling period.

Set a jug or a bucket of water near small tomato transplants, and enclose both the plants and the jug under a cover to create a warmer microclimate. Place larger garbage cans or drums under and between fig or citrus trees for added warmth.

Wind machines: Although impractical for home gardeners, wind machines are used by com-

Figure 8. A wind machine used to protect crops during radiative frosts.

mercial fruit and vegetable growers throughout the United States to protect crops during radiative frosts (Fig. 8).

Wind machines help break up temperature inversions by whipping cold air upward off the ground and pulling the warmer air above the inversion back down to the tree tops and plant canopies.

A single wind machine can protect 5 to 10 acres of horticultural crops, depending on its design. Wind machines are not helpful in advective freezes.

Protection from advective freezes

It is harder to protect against advective freezes than radiative frosts. The wind in advective freezes quickly cools plant tissues and displaces any heat provided. By themselves, the lightweight covers and blankets that protect so well during a radiative frost will provide little to no protection in a severe freeze.

Helpful measures during advective freezes include providing a heat source and covers, windbreaks, banks, and mulches.

Heat and cover: Adding a source of heat beneath a cover can make a big difference, especially if you seal or secure the cover to keep wind from moving the warmer air out from under it.

Common heat sources include a mechanic's light, a clamp-on floodlight with a heat lamp bulb, and a string of Christmas lights—the ones with large bulbs, not the small twinkling bulbs that emit little heat.

Check for shorts in the wiring, and make sure rain or other moisture can't get into the fixtures. Don't allow a hot light bulb to come close to plant tissues or it can cause damage. Also recognize that hot bulbs or an electrical malfunction can cause a disastrous fire (Fig. 9).

For covers, polyethylene films can help maintain temperatures during advective freezes, especially when partnered with blankets (with the film on top).

Semi-permanent covers: Another way to prevent or reduce advective freeze injury is to use semi-permanent box-shaped frames, tunnels, or hoop houses. Made of lumber or PVC pipe, these frames

Figure 9. a) Plants covered and warmed with lights, and **b)** burned remnants of a plant and cover.

can be covered in 4 mil or heavier polyethylene film (UV stabilized for longer life) and heated with lights, water barrels, or sprinklers. The cover and heat source create a greenhouse-like environment during harsh freeze conditions.

Semi-permanent covers work well when placed over a bed or down a row of vegetable plants or closely spaced trees. To make the frames:

1. Drive short sections of ⅜-inch rebar or other peg-type material into the soil along two sides of the bed or row. Space the pegs about 4 feet apart along each side.
2. Slide the ends of ½- to 1-inch PVC pipe over the row and into the pegs to form a series of arched hoops (Fig. 10).
3. Brace the top with wire or additional PVC pipe.
4. Cover the hoops with clear plastic sheeting

Frames can be built around a single tree or over beds or clusters of closely spaced plants. Because the plants covered in hoop tunnels or frames can overheat quickly on days with full sun, ventilate the frames after the freeze danger has passed.

For more information on winter tunnel protection, see http://aggie-horticulture.tamu.edu /fruit-nut/files/2010/10/Low-Tunnel-Strawberry-Guide-for-Home-Gardeners-on-the-Texas-High-Plains-Final.pdf.

Windbreaks: During severe advective freezes, windbreaks can offer some protection for plants. Useful windbreaks include buildings, natural vegetation belts, and purposefully planted rows of trees and hedges. They slow the wind, enabling the active measures to provide heat to be more effective.

Figure 10. Arched hoops made of PVC pipe used to make a semi-permanent frame.

Figure 11. Soil mounded, or banked, around the graft union or crown to protect against freezing.

The south sides of buildings and densely wooded vegetative areas create slight microclimate advantages for citrus and other freeze-susceptible plants; often these sites are where we find survivors after a severe advective freeze.

Banks: The practice of mounding soil or other materials around the graft union or crown of plants is called *banking* (Fig. 11). Citrus growers have used this tactic for over a hundred years to quickly regrow the grafted part of the tree if a freeze kills the top.

Although many people wrap tree trunks with quilts or pile up hay, leaves, or mulch around the trees, the most protective material for banking is soil. Whereas mulch or blankets must use their own insulating properties to slow heat loss, soil transfers the earth's heat to the plant parts that it touches. In Texas, the topsoil may be quite warm in winter (35 to over 50°F).

To build a soil bank, use loose, medium-textured topsoil. Make sure that the base of the bank contacts bare soil, rather than grass or mulch. These other materials will break the thermal transfer of heat from the earth to the bank.

Banks can remain in place throughout the winter. Remove them in early spring as soon as the threat of freezes has passed. Leaving them around trees too long can lead to root or trunk disease.

Mulch: Mulch can protect perennials, strawberries, and other marginally hardy plants from cold Texas weather. The mulch's insulating properties will enable the plant's crown and roots to survive the winter.

After the perennials have died back, prune them near the soil and cover them with a thick mulch of hay or leaves to hold in the soil's warmth. The crown and roots will stay warmer and in better shape to grow when warm weather returns.

Protection with sprinklers

Commercial fruit growers have learned that water sprinklers applying the right volume and frequency of water droplets can protect leaves, branches, blossoms, and even fruit from frost and freeze injury.

As a gallon of water freezes completely, it gives off 1,200 BTUs of heat, in addition to the BTUs (described previously for water in containers) it produces for each degree it drops down to freezing. Ice formed on the branches and limbs of sprinkled plants is evidence of heat being applied to those plant parts.

Because water releases heat quickly when it freezes, it must be applied continuously to maintain the heating process. If you apply enough water continuously, it will offset the cooling effects of the cold air, wind, and radiational cooling.

Know the amount of water that the plants need for adequate warming. If you apply too little water or stop sprinkling at any time during the night, the plants may sustain more damage than those not watered at all. Wind blowing over the water and ice will cause evaporative cooling that could reduce the tissue temperature below what it would have been with no water on them.

When using overhead rotating sprinklers to protect a crop such as strawberries or grapes in an open field, apply 0.12 to 0.24 inch of water per acre per hour, which is 54 to 108 gallons of water per minute per acre. Although applying more water would create more heat, it would also create more ice loading and saturate the roots.

To protect citrus trees, direct the sprinkler wetting pattern at the lower trunk and graft union as well as the mid-canopy area (Fig. 12). Rates of 10 to 30 gallons per hour per tree have protected citrus trees effectively.

Sprinkling the mid and lower canopy protects the tree's core without breaking off many lighter branches and limbs from too much ice loading. It also reduces evaporative cooling of the most wind-exposed leaves and branches of the tree.

To protect peaches and other spring-blooming fruit trees during a radiative frost, direct the sprinklers toward the ground under the tree to generate heat, which will then rise through the limbs and emerging flower buds in the canopy. Do not use this method in an advective freeze; the wind will negate any benefit to sprinkling under the trees.

Figure 12. Ice formed after a sprinkler was used to wet the lower trunk and graft union and the mid-canopy area of a citrus tree.

A common misconception among home gardeners is that the ice formed on plants from sprinklers insulates the plant against the cold. In reality, ice is a poor insulator, so once new droplets of water stop being applied, the leaves and branches will continue to cool below freezing and may be damaged.

The timing and duration of watering are critical when irrigating for frost or freeze protection. You must start watering before the air temperature reaches 32°F (to prevent ice from stopping up the sprinklers) and continue to water through the night and next morning until the temperature rises far enough above freezing that the ice is rapidly melting.

Although sprinkling can protect plants in some situations, it requires a lot of water and may create heavy ice that can flatten garden plants and break up trees and shrubs.

Protecting container plants

Because the roots of plants growing in containers lack the insulation of the earth, they can get much colder than the roots of in-ground plants. Roots are often less hardy than the top parts of the plant; they may die if the temperature in the container drops much below 32°F.

A good way to protect valuable container plants during a killing freeze is to move them to a garage or other protected location. Another option is to move the containers close together on a protected side of the home or other structure.

Water the plants thoroughly to increase the amount of heat produced in the container as it cools or freezes. For added protection, pile mulch, leaves, or hay over and among the containers and cover them with a frost blanket or other cover.

Assessing damage

After a freeze or frost, the leaves of damaged herbaceous plants may immediately appear withered and water soaked. However, the freeze injury to the twigs, branches, or trunks often doesn't appear on shrubs and trees right away. Wait a few days and then use a knife or thumbnail to scrape back the outer bark on young branches. Freeze-damaged areas will be brown beneath the bark; healthy tissues will be green or a healthy creamy color (Fig. 13).

Figure 13. Brown freeze-damaged area (right) and the creamy color of the live, healthy part of a stem.

Delay pruning until time reveals the areas that are living and dead and until the threat of additional frosts or freezes has passed. Leaving dead limbs and foliage at the tops of plants will help protect the lower leaves and branches from nighttime radiation loss. Pruning after a freeze does not improve the outcome. Also, plants that are pruned tend to be invigorated more quickly, which may set them up for further damage in Texas's unpredictable cycling of warm and cold temperatures.

All protective strategies have limitations in their ability to prevent damage or even death of plants. Occasional severe frosts or freezes may undermine even the best efforts, especially when the plants are at vulnerable stages of growth and development. Combining strategies (for example: locating plants in protected areas, watering bare ground before a freeze, and using covers and supplemental heating) provides the best opportunity to keep valuable plants alive and well during harsh winters.

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