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Cold Protection Methods[1]

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INTRODUCTION TO YOUNG TREE COLD PROTECTION

Protecting young trees from cold damage is a difficult task which has been complicated by several factors in the last decade. These complications include a significant increase in the number of young trees planted over the last several years, increases in cost of fuel, equipment and labor and an increase in the number and severity of freezes. The problems of young tree care, a shortage of trees and increasingly frequent freezes have generated a new interest in protecting young citrus trees from possible damage by cold. Since young trees are small and occupy a relatively small percentage of a planted grove acre, protection by most active means is not particularly effective. This is especially true of heating with fossil fuel sources which are now quite expensive in addition to being inefficient for young tree protection. Wind machines could be considered for protection, but their use is limited to calm nights with temperature inversions and the cost of acquisition and operation of this equipment could not be economically justified for non-bearing groves. Irrigation for cold protection is a possibility and is now widely used in many young groves where properly designed and maintained microsprinkler systems are in place. Such systems require uninteruptible power sources to avoid problems of electrical blackouts. Many young citrus trees are placed in a situation where active cold protection measures are difficult, if not impossible, and growers have to rely upon passive means of cold protection. Some of the more important passive cold protection measures include cultivar and rootstock selection, site selection, clean cultivation, pre-freeze irrigation and the use of banks and wraps.

COMPARISON OF METHODS

High fuel cost has made grove heating during freeze nights prohibitively expensive except for high value crops. Wind machines are effective under some conditions, but they require maintenance and need a strong temperature inversion for optimum effectiveness. Fog can provide protection, but light winds can blow the fog away from the grove and obscure nearby roadways. High volume overhead sprinkler irrigation has been used effectively on limes and avocadoes in south Florida where temperatures do not normally go far below freezing. In central and north Florida, where temperatures are usually colder, overhead sprinklers should not be used on large citrus trees because the weight of the ice formed can break off limbs and cause tree collapse. With overhead systems, all leaves are wetted and susceptible to damaging evaporative cooling during low humidity or windy freezes. Many trees were killed in the windy 1962 freeze when overhead sprinklers were used. Because of the cost of fuel, microsprinkler irrigation

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is rapidly becoming the preferred method for providing cold protection. This type of irrigation works particularly well for resets and the lower trunk and branches of young trees. However, once microsprinkler irrigation has begun, it must be continued until the grove temperature rises above freezing. If irrigation stops before then, the trees will likely be more damaged than if the irrigation continued. Banking very effectively provides cold protection to the trunks of young trees. However, banks are time consuming to erect and can produce some pest and cultural problems. The grower can avoid some of these problems by using tree wraps, which can be left on for an extended period of time once installed. While tree wraps as a whole are effective for cold protection, they are not as effective as banking. Protection varies greatly depending on the type of tree wrap used. Table 1 compares energy requirements for the various methods of cold protection discussed here.

SOIL BANKING

Soil banking (Figure 1) consists of placing a mound of soil around the tree's trunk to protect the bud union and trunk from cold. It is one of the most efficient cold protection methods for young trees and has been used with success for many years.

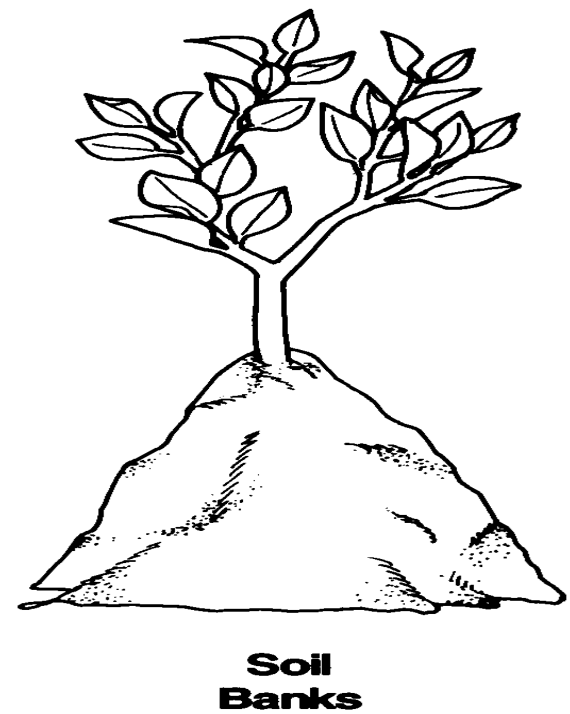

Figure 1. Soil bank

Banking principles

Since the soil stores heat from the sun during the day and releases it at night heat deep in the soil moves up to the surface by conduction and is lost to the air by radiation. By mounding soil around the trunk of a tree (banking), heat is conducted through the soil and into the protected area of the young tree. Thus, banking protects by conduction and insulation as well.

When to bank

A definite answer to the question of when to bank has not been derived. It would be most efficient if trees were banked the day before a freeze, but the state of the art of weather forecasting does not permit this luxury. Growers in much of south Florida do not bank at all since that area has such a low cold damage probability. However, growers in the north and much of central Florida realize the high probability of cold damage and routinely bank young trees in the fall as a regular production practice. A good rule of thumb is to try to have all trees banked by November 15 for the northern areas and no later than mid-December for the rest of the state.

Making the Bank

Banks can be constructed with a shovel or hoe, a blade on a tractor or similar tool, or with a banking machine. Build them as high as reasonable, up into the scaffold limbs whenever possible. Higher banks afford more protection, but they also require more labor and expense to build. Use only soil which is free of weeds, sticks, bags or other trash as these will invite damage from insects and disease. Watch banks carefully during the winter since wind and rain may erode them. Rapid recovery of freeze-damaged trees will be the payoff for a good banking job.

Unbanking

Trees can be safely unbanked as soon as the danger of cold weather has passed. In most areas this will be in mid or late February. If banks remain on the trees too long in warm weather, disease and insect problems increase and there is danger of a physiological bark sloughing disorder (sweating) which can quickly kill the young tree. Unbanking should be supervised just as closely as banking to prevent tree damage from careless equipment operation. Also, care must be taken to ensure the bank is removed completely and the soil carefully leveled around the young tree. Leaving too much soil around the tree trunk may encourage foot rot in the susceptible scion portion of the tree.

Banking Hazards

Tree Damage

Careless operation of equipment may break limbs, skin trunks and even destroy trees. Equipment operators must be conscientious and well-trained if the operation is to be a success. Broken limbs and skinned trunks should be treated with a good water-repellent pruning paint or fungicide before being covered with soil. Some mechanical equipment used for banking removes considerable soil from a relatively small area, resulting in damage to roots near the soil surface. The use of such equipment should be avoided or care should be taken to make sure damage is minimized.

Diseases and Insects

Fungal disease can sometimes be a problem when trees are banked. Placing soil on the susceptible scion portion of the young citrus tree may predispose the plant to foot rot if conditions are optimal for development of the fungus. Application of a suitable fungicide before banking will help reduce the incidence of foot rot. Ants and termites may sometimes become a problem in banks, particularly if there is trash in the soil used to construct the banks. Problems such as these can be dealt with as they occur or a preventive insecticide can be sprayed at the time of banking. Many growers routinely spray trees with a suitable insecticide-fungicide mixture just before banking as an insurance measure. One hundred gallons of spray should treat 400 to 600 trees if properly applied.

Banking Considerations

These factors should be taken into consideration before choosing banking as a cold protection method:

1. Soil banks must be put up before danger of cold and removed as soon as possible after the threat of cold has passed.
2. Labor to build banks is expensive.
3. Hot periods during winter months may necessitate early removal of at least a portion of the bank before the danger of cold is over.
4. Construction of banks is often hindered by weeds or in the case of larger trees, overhanging limbs.

Soil Bank Summary

Advantages

1. Excellent insulating value (12 - 15° above air temperature in most cases)
2. Sprout inhibitor
3. Conforms well to large or irregularly shaped trees
4. No cost for material, only labor

Disadvantages

1. Must be constructed and taken down seasonally
2. Difficult to maintain
3. Occasional problems with bark sloughing and foot rot
4. Moderate insect and disease problems
5. Must be removed after freeze damage to allow regrowth
6. Labor cost is expensive

TREE WRAPS

Theory of Cold Protection

Tree wraps are most useful in protecting young citrus trees during mild to moderate freezes or in traditionally warmer locations within the state. Tree wraps protect only the trunk, and consequently leaf loss can occur during moderate or severe freezes. Wraps work by delaying, but not preventing, heat loss from the tree trunk as air temperatures decrease. Temperatures under tree wraps generally are 0° to 6°F higher than air temperatures, depending on the type of wrap. However, the tree produces and stores very little heat, and during severe freezes of long durations the temperatures under most wraps will approach air temperatures. Wraps are most effective during freezes of short durations where temperatures drop rapidly. They are less effective, however, during freezes where temperatures decrease slowly and remain low for protracted periods. The effectiveness of the wrap is related to the insulating value of the wrap material. Consequently, wrapping trunks with thin-walled materials is ineffective for temperature control, while thicker insulating materials are more effective.

Wrapping

Most tree wraps, unlike soil banks, can be attached anytime during the year and left on the tree throughout the year or even for several years. However, some types of wraps, like those made of poor insulating materials or clear plastic, may damage or even kill the tree due to excessive daytime trunk temperatures during the summer.

When freeze damage occurs, wraps should be removed or pushed down to allow for growth of new shoots. Wraps should be properly positioned and fastened around the trunk for best results. It is important to cover the entire lower trunk, especially at the base.

Heating Effects

Insulating materials are used extensively in most tree wraps to provide cold protection. Since insulation holds heat in, protection is provided by slowing down the loss of heat from young tree trunks, thus making them warmer. However since there is very little heat stored in the trunk of a young citrus tree, wraps utilizing insulation alone have limited effectiveness.

Dormancy Effects

The degree of dormancy of young citrus trees is a function of environment, and measures to slow the growth of trees usually results in dormancy and a better ability to tolerate low temperatures. Insulating materials in some cases may help to keep tree trunks cool during daylight hours resulting in greater dormancy and an increased tolerance to low temperatures. Though not substantiated by research, the principle is confirmed by observation. Possible effects of light on tree dormancy is speculative but observations support the theory. Trees wrapped with opaque materials rarely sprout under such wraps because light is excluded. Sprouting is evidence of growth and lack of dormancy, so materials which block light may help to contribute to tree dormancy.

Use of Liquids

Some wraps utilize pouches of liquid (usually with an ice nucleator in solution) to furnish additional heat inside the wrap, next to the tree trunk. When liquids freeze, heat of fusion is released which can generate considerable heat. When this heat is released within the confines of an insulating material, and next to the tree trunk, it can be quite effective.

Types of Tree Wraps

Selection of the proper tree wrap for a particular grove depends on a number of factors including cost, ease of installation and probability of freeze damage. For example, growers in northern regions of the state should choose wraps with good insulating qualities, while growers in warmer southern locations may opt for less costly, thinner wraps. Tree wraps also inhibit sprouts and protect trunks from herbicide and mechanical damage. Consequently, no one wrap is best for all situations.

Fiberglass Wrap

The advantages and disadvantages of fiberglass wrap (Figure 2) are discussed below.

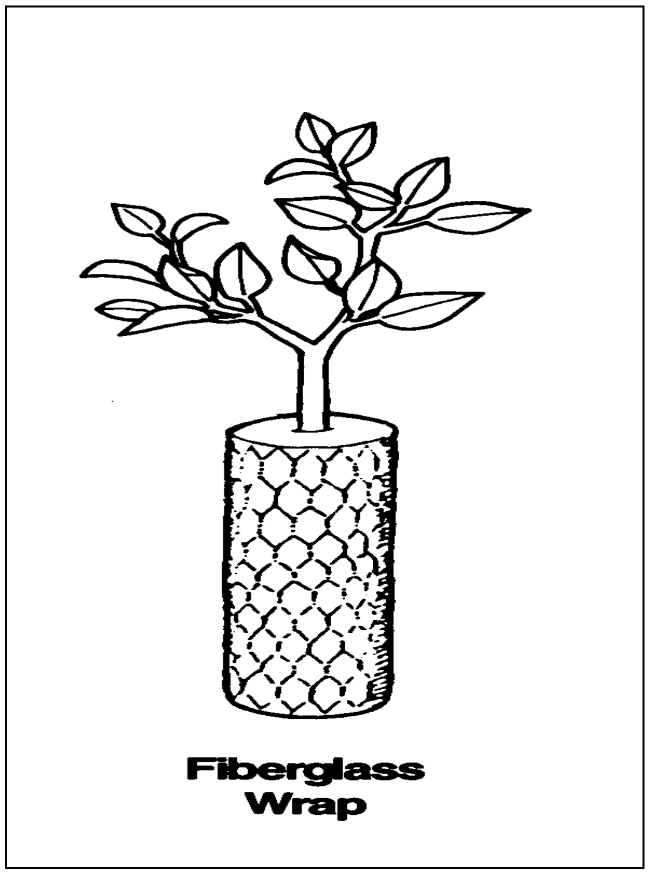

Figure 2. Fiberglass wrap

Advantages

1. High insulating value (3 - 6° above air temperature)
2. Moderately durable
3. Sprout Inhibitor
4. Can be pushed down to allow for regrowth following a freeze
5. Inert, will not hold water for long periods of time, rarely causes foot rot problems
6. Moderately inexpensive
7. Conforms well to large or irregularly shaped trunks

Disadvantages

1. More difficult to install and handle than some other wraps
2. Moderate ant problems

Polyurethane foam

The advantages and disadvantages of polyurethane wrap (Figure 3) are listed below.

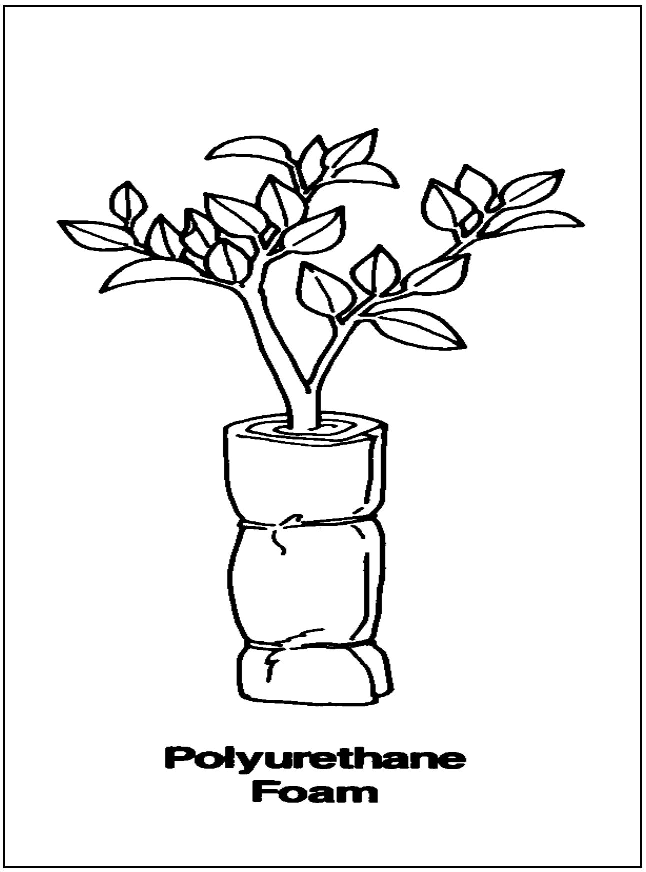

Figure 3. Polyurethane foam wrap

Advantages

1. High insulating value (3 - 6° above air temperature)
2. Moderately durable
3. Sprout Inhibitor
4. Moderately inexpensive
5. Moderately easy to handle and install
6. Conforms well to large or irregularly shaped trunks

Disadvantages

1. May become waterlogged, particularly if used with irrigation
2. Sunlight deteriorates some wraps
3. Foot rot is an occasional problem
4. Must be removed after freeze damage to allow regrowth

Rigid Polystyrene Foam (Thick-Walled)

Listed below are the advantages and disadvantages of thick-walled rigid polystyrene foam (Figure 4).

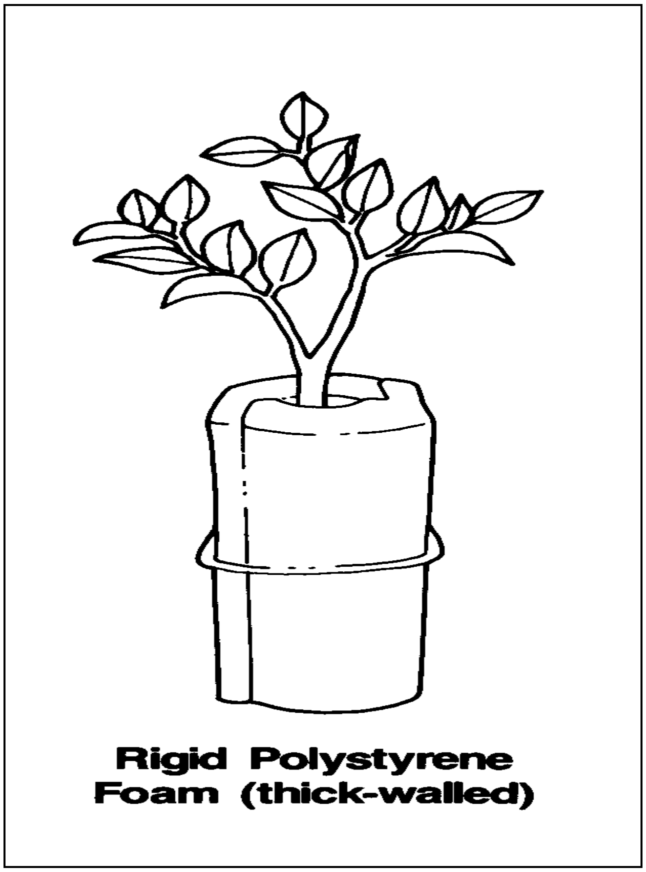

Figure 4. Thick-walled rigid polystyrene foam

Advantages

1. Very high insulating value (4 - 8° above air temperature)
2. Very durable
3. Moderate sprout inhibitor
4. Will not hold water, rarely foot rot problems
5. Easy to handle and install

Disadvantages

1. Expensive
2. Moderate ant problems
3. Must be removed after freeze damage to allow for growth
4. Subject to loosening by animals, may fit poorly on irregularly shaped trunks

Rigid Polystyrene Foam (Thin- Walled)

Below are listed the advantages and disadvantages of thin-walled rigid polystyrene foam wrap (Figure 5).

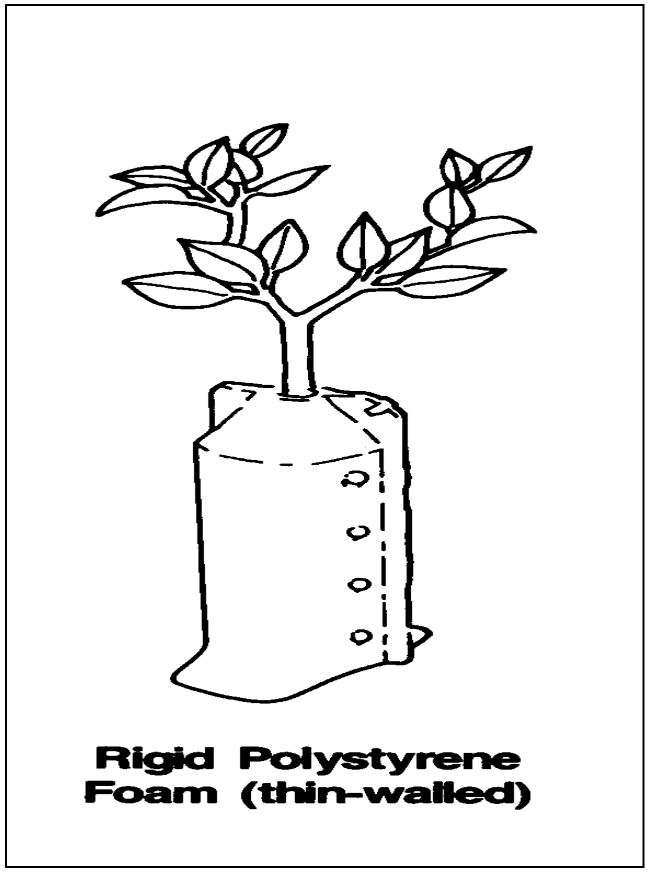

Figure 5. Thin-walled rigid polystyrene foam

Advantages

1. Low to moderate durability
2. Sprout inhibitor
3. Will not hold water, no foot rot problems
4. Inexpensive
5. Moderately easy to handle and install

Disadvantages

1. Low insulating value (0 - 2° above air temperature)
2. Moderate to severe ant problems
3. Must be removed after freeze damage to allow regrowth
4. Not suited for large, rapidly growing trees, may fit poorly on irregularly shaped trunks

Closed Cell Polyethylene Foam

Discussed below are the advantages and disadvantages of closed-cell polyethylene foam (Figure 6).

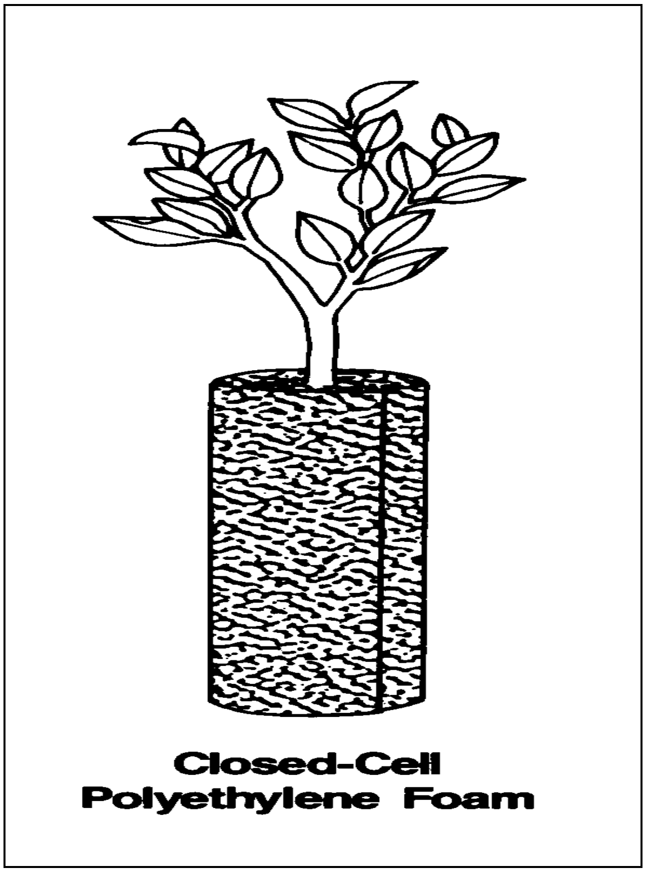

Figure 6. Closed-cell polyethylene foam

Advantages

1. Moderate insulating value (2 - 4° above air temperature)
2. Moderately durable
3. Sprout inhibitor
4. Inert, will not hold water, rarely causes foot rot problems.
5. Easy to handle and install
6. Some models use irrigation water supply tube inside for extra protection.

Disadvantages

1. Moderately expensive
2. Ant problems are severe in some areas
3. Must be removed after freeze damage to allow regrowth
4. May cause bark sloughing and fit poorly on large or irregularly-shaped trunks

MICROSPRINKLER IRRIGATION

Overhead, high-volume sprinklers have been used successfully in citrus nurseries for years as a means of cold protection. Recently, there has been interest in using low-volume microsprinklers to protect young trees in the field; however, success varies with the type of system, application rates, type of freeze (advective vs. radiative), and severity of the freeze.

Theory of Protection

Water protects young trees by transferring heat to the tree and the environment. The heat is provided from two sources, sensible heat and the latent heat of fusion. Most irrigation water comes out of the ground at 68° to 72°F, depending on the depth of the well. In fact, some artesian wells provide water of 80°F or more. As the water is sprayed into the air, it releases this stored (sensible) heat. However, by the time the water reaches the tree it has lost most of its energy, particularly for low volume microsprinkler systems. Consequently, the major source of heat from irrigation is provided when the water changes to ice (latent heat of fusion). As long as water is constantly changing to ice the temperature of the ice-water mixture will remain at 32°F. The higher the rate of water application to a given area, the greater the amount of heat energy that is applied.

The major problems in the use of irrigation for cold protection occur when inadequate amounts of water are applied or under windy (advective) conditions. Evaporative cooling, which removes 7.5 times the energy added by heat of fusion, may cause severe reductions in temperature under windy conditions, particularly when inadequate amounts of water are used. In addition, most irrigation systems will not protect the upper portion of the canopy.

Types of Microsprinkler Systems

A number of low-volume microsprinklers which can be used for cold protection of young citrus trees are currently available. As with tree wraps, no one system is best for a given grove situation. Remember that microsprinkler irrigation is primarily used to irrigate trees, and practical irrigation designs may not necessarily provide optimum cold protection. Again, cost, ease of operation, and especially probability of freeze damage should be considered when selecting an irrigation system. However, the key to successful cold protection using any microsprinkler system is providing a continuous and adequate volume of water directly to the trunk of the tree. This is particularly true during advective freezes where water may be blown away from the trunk.

It is generally advisable to place the emitter northwest of the tree, approximately 1 yard or less from the trunk. Emitters should be attached to risers for greatest tree trunk protection. Improper placement or inadequate spray coverage will greatly lessen the effectiveness of the irrigation. A 90° spray pattern which concentrates the water on the trunk and lower limbs gives cold protection superior to a 360° or 180° pattern. Inverted cone sprinklers positioned above the wrap in the tree also give adequate protection. The volume of water applied depends on the amount of cold protection required. Generally, 10 gallons per hour (gph) applied directly to the trunk in a 90° pattern will provide adequate cold protection during most freezes.

Wraps Plus Irrigation

This combination of cold protection measures provides protection by insulation plus heat of fusion from water freezing on the wrap, and in some cases, water actually being piped through the wrap to provide even more protection. Spraying water on wraps in sufficient volume and without interruption will theoretically not allow temperatures to fall below 32°F. Furthermore, if ground water is piped through the wrap prior to spraying it externally, additional protection could be provided.

When used in combination with adequate irrigation most tree wraps provide cold protection to the trunk. However, only wraps with high insulating characteristics provide protection when irrigation is discontinued due to a power outage or break in the irrigation lines. A combination of tree wraps and microsprinkler irrigation provides low cost insurance against such problems.

COLD PROTECTION USING HEATERS

The greatly increased cost of fuel has practically eliminated heaters from the growers cold protection strategy. However, heaters can still be cost effective when used to protect high-value citrus cultivars.

Using Heaters

Orchard heaters provide heat by direct radiation and convection. Stack heaters give out 25-30 percent radiant heat, which moves along a straight line from the heater to the trees. Air around the immediate area of the heater is heated by convection; some of this heat is lost if it rises above the level of the orchard. Because of the need for fuel-burning efficiency and pollution reduction, orchard heaters have evolved to the upright stack design. Vaporizing pot-type stack heat (for example, jumbo cones and return stacks) have the advantage of low initial cost, maneuverability, and versatility. However, fuel can be lost due to spillage, leakage, and boiling of fuel left in the heaters after they are extinguished. Labor requirements for lighting and refueling heaters are high, and an additional crew is frequently needed to refuel heaters if several nights of freeze protection are required. Compared to individual stack heaters, centralized pressure fuel systems burning diesel fuel and liquid propane are more fuel-efficient and offer considerable labor savings. Fuel storage for any heating system is a big expense and environmental liability.

Energy Saving Tips

1. Maintain heaters in good working order. Periodically clean the stacks for most efficient burning of fuel and to keep emissions within the standards specified by air pollution laws.
2. Have sufficient thermographs or thermometers throughout the grove area.
3. Large groves can generally be heated more efficiently than small groves. To protect grove borders, additional heaters must be placed along the edges of the grove, especially on north and west sides.
4. Calculate temperature drop vs. time throughout the night to better determine when heating should be started.
5. It is important to light heaters one to two degrees above the lethal temperature of leaves or

blossoms and buds. If fruit is to be protected, begin protection one or two hours after the critical freezing temperature of fruit has been reached, since the fruit has more mass than buds and cools more slowly or use a thermometer to determine the internal temperature of the fruit.

6. It is frequently possible to stabilize temperatures during the initial phase of protection by lighting every other row of heaters or by lighting central systems and then turning the pressure down. Additional heaters can then be lit or line pressure can be raised slightly to maintain the temperature in the grove as temperatures drop outside the heated area.
7. Many small heaters generally provide more efficient heat distribution than a few large ones. This point became particularly important with higher fuel costs. The additional capital outlay of a greater number of heaters could be returned through more efficient orchard heating.
8. Be familiar with cold areas in your grove so that heaters in those areas can be lit first.

Minimizing Heating Requirements

Selecting the proper temperature for lighting heaters or starting any system of cold protection can affect fuel savings. For example, using climatic data for Bartow, Florida, protecting a grove nine out of ten years at 28°F. would require at least 26 hours of heating per winter. However, if the crop would tolerate 24°F., the grower would only have to heat five hours, using one-fifth as much fuel. Citrus fruit will withstand temperatures of 28°F for approximately two hours. But leaves and twigs (fruiting surface) will often withstand 24°F or lower. With the uncertain future of fuel supplies, growers may seriously consider only protecting the fruiting surface of the tree and allowing the fruit to freeze. The fruit may still be used for processing if it is harvested within a week to ten days following the freeze. Leaf freezing points are a good estimate of the temperature at which leaves twigs and wood freeze. Often, twigs and leaves will freeze at or near 24°F in the early fall, but may withstand 22°F or slightly lower temperatures during mid-winter.

WIND MACHINES

Wind machines offer some excellent advantages in cold protection because they minimize labor requirements, consume less fuel per acre protected and require less fuel storage than heaters. They are permanently located in the grove and have a low operational cost per acre. Fuel requirements for wind machines are about 10 gal/hr or 1 gal/acre/hr compared to 10-35 gal/acre/hr with heaters. These advantages must be weighed against the disadvantages of rather high capital costs and the failure of the wind machine to provide adequate cold protection under all conditions. Wind machines are dependent on having an inversion--that is, warmer air at approximately 40-50 feet above the orchard. A temperature inversion of at least 5° difference is necessary and an inversion of 10-15°F makes the wind machine very effective. They are most beneficial when located in low pockets where they mix cold, heavy air, which settles there, with warmer air above. In general, one can use the rule of thumb that 10 horsepower is required to protect one acre. Usually, one wind machine is required for each 10 acre block. However, the increase in temperatures are highest nearest the machine and decrease toward the edge of area protection. Heaters can frequently be used near the edge of the area protected to remedy this situation. Start wind machines when temperatures are two to three degrees above the lethal temperature. Because of the low cost of running a wind machine, plus the fact that it can only raise the temperature a few degrees, it is necessary to start the wind machine early. It is very important that wind machines be run at the rpm specified by the manufacturer, since they provide considerably less protection when operated at a lower speed.

Helicopters are sometimes used as a cold-protection device, if they are stationed nearby. Otherwise, they are too expensive. They are utilized as a large, moving wind machine. When helicopters are used effectively, a number of temperature monitors are required in the grove to determine the coldest areas and the frequency of passes the helicopter must make. Monitors should turn on a light when temperatures reach a critical value. Rapid refueling or more than one helicopter may be necessary since protection cannot be halted once temperatures are below the critical point.

Heating in conjunction with wind machines provide better protection at lower cost than heaters alone. For example, an orchard requiring 35 heaters per acre without the use of wind machines would require 15 heaters per acre with wind machines. Heaters plus wind machines and good air temperature inversions would permit heaters to be used less than half the time, which would reduce fuel consumption and increase the heater's life span.

Table 1. Energy requirements of various cold protection methods for young citrus trees

	Fuel Consumption	
Method	gal/hr/acre	BTUs/hr/acre (in thousands)
Heaters	20 - 40	2,800 - 5,600
Wind machines	0.5 - 1.5	70 - 210
High volume sprinklers	0.25 - 0.75	35 - 105
Low volume sprinklers	0.10 - 0.25	14 - 35
Source: T. R. Mee		