

## **Frost Protection**

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A grower must determine for himself whether or not it will pay under his conditions to provide protection against cold. This decision should be based on past experience in the orchard or in adjacent orchards under similar conditions. If the loss from cold has been great enough to justify the expense of providing protection, it is then necessary to select the kind of equipment which will provide the amount of protection needed.

In any discussion of protection from frost it is important to keep in mind some of the characteristics of heat. Cold is nothing in itself. It is the absence of heat. Injury from frost results from the loss of heat. The only protection against cold, therefore, is to conserve natural heat or to add heat by artificial means.

### **The Radiation of Heat**

Heat comes to the Earth from the sun as radiant energy and is absorbed by solid objects such as trees and soil. Heat rays are in many ways like light rays although they are not visible. Like light rays they travel in straight lines at a speed of 180,000 miles per second and they have little effect on the air as they pass through. Like light rays they are given off again by objects which they strike. We in this audience are all radiating heat to each other and to the objects which surround us. In this room we feel warm because the heat of our bodies is being radiated back to us from the walls and ceiling of the room and the air is warm because it comes in contact with warm objects.

At night the Earth receives little heat from cold outer space but solid objects continue to radiate heat to the sky. Unless absorbed by some solid object, this heat escapes and is 180,000 miles away in one second. Since the air is not greatly affected by the passage of heat rays the upper air remains nearly as warm as in the daytime but the air next to the ground is cooled by contact with the soil, trees and other solid objects. When frost occurs under these conditions, we call it a "radiation frost" and we say there is a ceiling of warm air.

If a breeze is blowing, the cold air is mixed with warm air from above and frost is less likely to occur. On hazy and cloudy nights the droplets of moisture in the air absorb heat rays and radiate them back to the earth. For this reason, the temperature falls much more slowly on cloudy nights than on clear nights and frost rarely occurs under these conditions. This effect is illustrated by the glow over a lighted city on a cloudy night. Light rays are intercepted by the droplets of water in the clouds and radiated back to the

Earth.

Occasionally a mass of cold air moves in from the north, cooling everything in its path. When frost occurs under these conditions, we have a freeze and there is no ceiling because the upper air is cold.

The most dependable protection against cold is provided by an adequate installation of orchard heaters. The loss of heat on cold nights will be approximately 1,000,000 B.T.U.s per hour. An installation of 45 to 50 oil burning heaters per acre will supply about three times this amount of heat and under most conditions will give adequate protection. This requires heaters, fuel, fuel storage, tank wagons, torches, thermometers, etc. The cost will be in the neighborhood of \$350 per acre for equipment. The cost of operation will be variable but it will range between \$20 and \$25 per acre. The operation of the heaters in avocado orchards creates a serious fire hazard because of the thick blanket of dry leaves which usually accumulates. Where this hazard can be overcome, heaters will give the most complete protection which is available; otherwise, fire may cause more damage than cold.

Wind machines do not give complete protection but under conditions where the hazard is not great they may give enough protection to justify their installation. Their cost will also be in the neighborhood of \$350 per acre and operating costs will be about \$3.00 per hour. Running time will usually be 25 to 100 hours per season.

When there is a ceiling, wind machines take warm air from above the orchard and mix it with the cold air which surrounds the trees. In this way the orchard temperature is increased. This increase commonly amounts to about 2 degrees but it may be even greater. Increases of 6 degrees have been observed. The temperature raise which may be expected 250 feet from the machine is in the neighborhood of one-third to one-fourth of the difference between the air temperature above the orchard and the air temperature in the orchard. For example, if the orchard temperature is 26°F. and the air temperature at the height of the wind machine is 38° F., the difference is twelve degrees. Under this set of conditions a raise of three to four degrees could be obtained. If the air movement in the orchard exceeds 2 miles per hour, any added turbulence caused by a wind machine will have little effect. If there is no warm air above the orchard, as is the case during a freeze, there will be no increase in temperature. If the upper air is colder than the air in the orchard, a wind machine will make the orchard colder. The effectiveness of wind machines has in some cases been increased when they are operated in combination with a few orchard heaters.

### **Why Exposed Fruit Becomes Colder**

As indicated before, solid objects radiate heat much faster than air. (This is why thermometers must be sheltered to measure air temperature.) As a result, exposed fruit frequently becomes colder than the surrounding air. If air at orchard temperature is blown over such a fruit, it raises the fruit temperature. In other words, the circulation of air through an orchard tends to minimize the difference between air temperature and fruit temperature and thus decrease the hazard to exposed fruit. This is a small factor because the amount of air moved past a given point by a wind machine is not great.

There is a third effect on some occasions. Its importance with avocados has not been determined. It is known that wet fruit frequently freezes more readily than dry fruit and since wind machines keep fruit dry longer they may delay formation of ice crystals in the fruit. The reason for this effect is as follows. As growers are aware, fruit often reaches temperatures below its freezing point without actually freezing. This is known as "undercooling" or "subcooling." Freezing does not begin till something starts the formation of ice crystals. When fruit is wet the water on the surface has a freezing point of 32° F. while the fruit may have a freezing point of 28° F.—a difference of four degrees. Water can undercool just as fruit does but it is most unlikely to go four degrees below its freezing point before ice crystals form. As a result, by the time a wet fruit has cooled to its freezing point, the water on its surface will be frozen and the ice crystals on the outside of the fruit will cause crystals to form in the fruit as soon as the freezing point of the fruit is reached. Under these conditions the fruit would not undercool at all.

The effects described above are relatively small and temperatures frequently fall below the range in which they operate.

### **The Effect of a Leaf-Mulch**

The soil acts as a reservoir of heat. During the day it receives heat and at night it radiates heat to the trees and out into space. Anything like a cover crop or leaf mulch insulates the soil and reduces absorption of heat during the day and retards radiation at night. For this reason, trees above a surface covered by leaves or anything which reduces the absorption of heat during the day will be more seriously affected by cold at night. To make the greatest use of the sun's energy, the soil must be kept bare and firm so it will absorb as much heat as possible in the daytime and release as much as possible during the night. This does not fit into the most approved method of handling soil in avocado orchards but it must be given consideration in any appraisal of the frost hazard.

Young trees may be protected by wrapping the trunks and main limbs with cornstalks or other suitable material. The leaves are left exposed to the light so they can function normally. It is better to let them freeze than to prevent their activity by cutting off light. The purpose of the wrapping is to insulate the tree. The wrapping should be two or three inches thick and firm enough to prevent free circulation of air. Well wrapped trees absorb less heat during the day but they lose heat more slowly at night. The tendency is for the wrapped trunks to stay near the average between night and day temperature.

### **Summary**

Some protection can be had by keeping the soil bare and firm. Young trees can be protected by wrapping the trunk and main limbs. Orchard heaters provide the most dependable protection against cold. Wind machines give limited protection.

1. On still nights when there is a ceiling of warm air above the orchard, they partially mix the warm air with the cold air near the ground and increase the orchard temperature a few degrees near the machine.

2. They tend to maintain exposed fruit more nearly at air temperatures.
3. They maintain conditions favorable to undercooling by keeping the fruit dry longer.
4. They have generally failed to give protection against a freeze.