

FROST PROTECTION FOR FRUIT CROPS

It is in the spring, from the first signs of bud swell through post bloom that fruit buds, flowers, developing fruit and emerging shoots are the most sensitive to low temperature (frost) injury.

Critical temperature (F °) of fruit buds at bloom.

Crop	T ₁₀ ^z	T ₅₀ ^y	T ₉₀ ^z
Apple	28		25
Pear	28		23
Peach	27		24
Tart cherry	28		25
Plum	27		23
Strawberry		30	

^z For 10 and 90% kill. *From* PM-1282

^y For 50% kill. *Published in:* Galletta, G.J, and D.G. Himelrick. 1990. *Small Fruit Crop Management.* Prentice Hall.

Critical temperatures (F °) of developing 'Concord' grapevine buds at different stages of development.*

Stage of Development	Bud Surface Moisture Status	
	Wet	Dry
Scale-crack	22	15
First-swell	24	18
Full-swell	26	19
Burst	26	21
Exposed Shoot	27	

* Values are LT₅₀, where 50% of the growing buds were killed. *Published in:* Galletta, G.J, and D.G. Himelrick. 1990. *Small Fruit Crop Management.* Prentice Hall.

The best protection for avoiding a spring frost is locating the fruit planting on a proper site. However, most sites are not perfect, and may benefit from additional frost protection. The investment in some form of frost protection or combination of systems may mean the difference between a full crop and total crop loss depending upon the system, and atmospheric conditions associated with the freeze. The following discussion is intended as a brief introduction to the types of freezes that can occur, and the frost protection systems that are available.

Type of Freeze

Freezing temperatures are classified into two categories based upon the atmospheric conditions associated with the freeze:

Advection Freeze: An advection freeze occurs under windy conditions when a large, dry, cold air mass, several thousand feet thick, moves into an area. This is the type of freeze we experience in Iowa when the wind is out of the north-west and an atmospheric high pressure cell is moving into the region. When this occurs, the air temperature is often colder than the plant temperature. Under such conditions, site location, as well as many frost protections systems, are of little benefit.

Radiation Freeze: A radiation freeze occurs when a dry cold air mass settles in an area when there is little or no wind and an absence of cloud cover during the night. This is associated with the center of an atmospheric high pressure cell moving into an area. Under such conditions, it can be relatively warm during the day with the sun warming the soil and plants. At night, this heat is slowly released to the atmosphere. Because there is little or no wind, the air stratifies forming an inversion layer of warmer air about 30 to 50 feet above the ground. Cooler dense air is trapped beneath the warm air, and continues to cool. As it does so, it settles near the ground and drains to lower elevations within the area. The air temperature at 50 feet may be anywhere from 3° to 10° F warmer than the air near the ground in the planting. Because there is very little air movement, and the fact that air, particularly dry air, is a poor conductor of heat, plant parts can be several degrees cooler than the surrounding air. It is under these conditions that proper site selection and all the frost protection systems can be beneficial in reducing crop loss.

Even in the middle of winter in Iowa when we frequently experience advection freezes associated with arctic cold waves, our coldest temperatures occur under radiation freeze conditions when the wind stops blowing and it is the sites at the lowest elevations that get the coldest. During the spring the emerging shoots, fruit buds, flowers and developing fruit are the most susceptible to low temperature injury, and it is during this period when radiation freezes present the greatest risk to the crop.

Frost Protection Systems

Over the years, a number of frost protection systems have been used with success being dependent upon the type of freeze experienced. The following lists the basic frost protection systems employed today, and points out their advantages and shortcomings:

Heaters: The use of heaters of various design, or lighting fires using various combustible materials are one of the oldest frost prevention systems. Today, because of environmental concerns, oil burning, stack heaters and liquefied gas distribution systems are about the only types of heaters still on the market. The principle of the system is to use a large number of small heat sources to heat the air as uniformly as possible up to the inversion layer. However, when the inversion layer is high, most of the heat produced (convective energy) goes straight up, and the only benefit from the heaters is the radiant energy generated. For radiant energy to be beneficial, the plant must be in a direct line to the heat source. With the present cost of fuel, and high labor requirements to light and maintain the heaters, they are the least cost effective approach to frost control. However, they are the only system that has proven to provide a reliable degree of protection during an advection freeze.

Tree fruit and grape growers have been known to pile their prunings near their plantings to burn during a freeze. This practice can actually cause more injury to the areas away from the fires. This is because large fires generate high amounts of convective energy that can break the inversion layer. This allows greater amounts of heat to escape to the atmosphere and in doing so, draws in more cold air from the surrounding area.

A common belief is that smoke generated from burning combustible materials will reflect the heat back to the ground in a similar manner as clouds do. The truth is smoke does not trap or reflect heat (infrared energy) back to the ground. Infrared energy passes right through smoke. All the smoke does is tell you where the inversion layer is located.

Sprinkler Irrigation: The use of overhead sprinkler irrigation for frost protection can be a cost effective approach if the system is also to be used for irrigating the crop, but carries a risk of doing more damage than the frost might otherwise do. The principle of sprinklers is that relatively warm water gives up heat upon contact with the colder air and/or foliage. When the temperature drops below freezing, the water freezes and releases additional energy to the leaves and fruit. With continued sprinkling at subfreezing temperatures, ice accumulation can snap off branches. Low level micro-sprinklers placed under trees and vines are an effective means of using water for frost control without the risk of limb breakage.

Sprinklers should be started before the temperature drops to freezing and run until the danger of freezing has passed. Particular attention must be given to the predicted dew point temperature. If

the predicted dew point is 5° below the anticipated low temperature, sprinkler irrigation will cause evaporative cooling and aggravate the cold injury rather than prevent it. This is particularly true under advection freeze conditions.

Other considerations when considering the use of sprinklers for frost protection are the availability of water for irrigation, and because frost protection may be needed on several successive nights, the soil drainage characteristic becomes important.

Wind Machines: Wind machines have proven to be one of the most cost effective methods or frost protection under radiation freeze conditions. However, because the air temperature is lower than the plant temperature during an advection freeze, wind machines used alone under such conditions may do more harm than if not used at all. Also, winds associated with advection freezes can do serious damage to most wind machines, consequently they are not recommended for use under such conditions.

The principle of the system is to move heavy cold air to prevent stratification, and allow the warmer inversion layer air to replace the colder air near the ground. To be most effective, wind machines should be started before the temperature drops below freezing. Depending upon the field layout and contour, a single large tower machine will effectively protect up to about 10 acres with a 10° temperature inversion differential at 50 feet. As the inversion strength (differential) weakens, the area of protection becomes less. For sites on variable terrain, contour heads are available to better direct the air flow as the propeller head rotates around to face all portions of the site. Because of cold air drift, the effective pattern of a wind machine is not circular, and sites for wind machine placement should be selected by a qualified professional only after an appropriate survey of the land and cold air drift conditions has been made.

There are three types of wind machines on the market:

1. Tower machines are the most common type. With a blade that is positioned at a slight tilt from perpendicular to the ground, they are designed to draw warm air from above down and mix it with the colder air at the surface as the head rotates around the tower.
2. Tower-less machines that are designed to blow the cold air near the ground upward to mix with the warmer air above and circulate back.
3. Ground-level mobile machines (frost fans) that blow cold air out of the site and permit warmer air from above to replace it can be effective depending on the strength of the inversion and contour of the site. These units are positioned near the highest point on a site in a natural air drainage pathway to improve the cold air flow.

Combining the use of wind machines with heaters under weak inversion conditions improves the effectiveness of both systems in raising the site temperature. However, due to the convective currents generated by the heaters, the effective area of the wind machine is reduced.

Wind machines can be powered by electric motors, gasoline/liquefied gas (LP) powered engines, or diesel engines. Some are also designed to run of a tractor's PTO shaft. Each has its advantages and disadvantages in terms of initial cost, operating cost, as well as other factors.

- **Electric:** Electrically powered wind machines are less expensive to purchase than those powered by gas/LP or diesel. They can be thermostatically controlled to start up when needed. They require a 440/480 volt, 3-phase hook up, and if economical power and line extensions are available, they can be the best choice. Generally they are more expensive to operate compared to gasoline powered units.
- **Gasoline:** Gasoline powered industrial engines have been a popular choice since they are most often less expensive to operate than electrical units and the owner can do the maintenance. One of the problems encountered with these units has been fuel theft.
- **Liquefied gas:** Liquefied gas (propane) conversions are available for gasoline powered units at an additional cost, but overcome the theft problem associated with gasoline. These industrial engines run equally well on LP. They will consume about a gallon per hour more than the same engine powered with gasoline, but based upon fuel costs, their operating cost is similar.
- **Diesel:** Even with reduced fuel consumption, lower fuel costs and longer engine life, diesel powered units have not been a popular choice because of the higher initial cost and relatively short season of usage. When the engine can be used for other purposes in the off-season, diesel power may be warranted and cost effective.
- **PTO:** Wind machines powered from a tractor's PTO offer the least expensive initial investment provided a tractor with sufficient PTO horsepower is already available. During the frost season, the need of the tractor for other purposes and convenience of hooking it up to the wind machine must be considered.

Helicopters: Helicopters are usually effective for frost control under the same conditions as wind machines. They are most effective when hovering or passing over the site at slow speeds (5 to 10 mph). However, helicopters must still be able to return over a portion of a site about every 5 to 6 minutes before air stratification re-occurs. They can provide protection for up to about 40 to 50 acres. Because of the high cost of hiring a helicopter (currently over \$500 per hour) for frost control and standby charges, a 1987 New York report found that if the annual average need for frost protection for 10 acres of apples exceeded 5 hours at \$350 per hour for hiring a helicopter, a grower would be ahead investing in a wind machine.

Other Protective Measures: Proper site selection is still the best measure for reducing the risk of a spring frost. Whether a frost protection system is installed or not, other cultural measures in and around the site can be taken to further reduce the risk of crop loss from a frost:

1. Plant on sites that are at least 50 feet above a valley floor.
2. Lay out planting rows parallel to the prevailing direction of the cold air drift.
3. Prune trees and vines properly to avoid blocking air movement. The removal of low hanging, dense branches is a must.
4. Prune out the lower portions of windbreaks to allow air to pass through to avoid the formation of a frost pocket. This practice will also aid in mixing the colder air near the ground with the warmer air above.
5. Keep natural swales, or other air drainage pathways open to insure good air drainage and elimination of frost pockets. This includes not planting in swales as well as removing undergrowth in areas below the site.

WIND MACHINE MANUFACTURERS AND DISTRIBUTORS: *

Orchard-Rite:

<http://www.orchard-rite.com/>

Orchard-Rite, Ltd.

P.O. Box 9308
Yakima, WA 98903
Ph: (509) 457-9196

Hi Quality

215 Silver St.
Delta, CO 81416
Ph: (970) 874-1178

Plummer Supply

2875 Plummer Park Lane
P.O. Box 177
Bradley, MI 49311
Ph: (800) 632-7731

Chinook:

H.F. Hauff Co.

1801 Presson Place
Yakima, WA 98002
Ph: (509) 248-0318

Phil Brown Welding Corp.

4689 8-Mile Road
Conklin, MI 49403
Ph: (616) 784-3046

Sentinel:

Vamco Ltd, Inc.

1460 So. Mirage
Lindsay, CA 93247
Ph: (559) 562-5185

<http://www.agplus.net/vamco.index.html>

SIS System:

Shur Farms

1890 N. 8th Street
Colton, CA 92325
Ph: (909) 825-2035

<http://shurfarms.com/>

Wilson Orchard & Vineyard Supply

1104 E. Mead Ave
Yakima, WA 98903
Ph: (509) 453-9983

<http://www.wilsonirr.com/>

* **Disclaimer Clause:** Listing of wind machine manufactures and distributors is not intended to be an endorsement to the exclusion of other companies that may offer similar products.