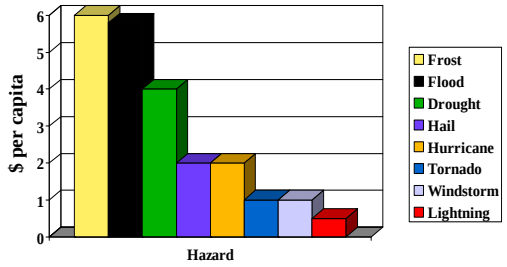
Grapevine Frost Protection

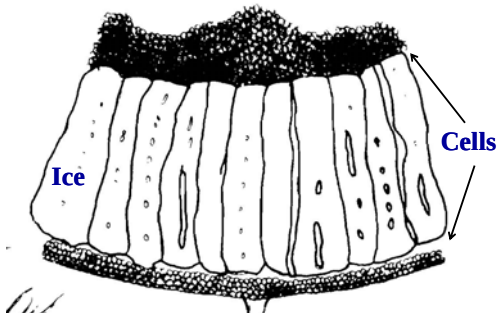
Richard L Snyder
University of California
Cooperative Extension

http://biomet.ucdavis.edu

Mean Annual Losses to Weather Hazards in the United States



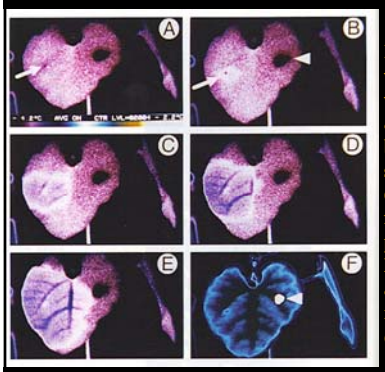
Intercellular Ice Crystal Formation



Prillieux (1869) cited by Levitt (1980)

Ice Formation

- Water Freezes below the Melting Point (0°C or 32°F)
- In the temperature range for Frost Damage (-5 to 0°C or 23 to 32°F), INA bacteria cause 99% of Ice Nucleation
- Ice forms on the surface and propagates inside



In A, on a dry leaf water with *P. syringae* was placed at the arrow and deionized water at black spot. The black spot is colder because of evaporation. Ice forms first at the bacteria and propagates through the leaf (B-E). Two minutes after the exothermic response dissipates, the deionized water freezes.

Wisniewski, Lindow and Ashworth (1997)

Critical Temperatures

The values shown below were determined in the laboratory and have not been checked extensively against field injury. These values are distributed as a guide for frost sensitivity of grapevines.

STAGE OF DEVELOPMENT DEFINITION		CRITICAL TEMPERATURES (°F)	
Stage	Description	T10	T90
Dormant	Closed bud, inactive.	<0	<0
First Swell	Buds increase in size, scales separate to show brown, fuzzy, young leaf tissue.	13	-3
Full Swell	Bud swells further, young leaves become pink. Still closed around growing point.	21	10
Bud Burst	Young Leaves separate at tip to show the growing point.	25	16
1st Leaf	First leaf is out of the bud, makes right angle with stem.	27	21
2nd Leaf	2nd leaf makes right angle with stem.	28	22
3rd Leaf		28	26
4th Leaf		28	27
5th Leaf		28	27

*Critical temperatures for 10 percent (T10) and 90 percent (T90) kill of primary buds.
E. L. Proebsting, V. P. Brummund and W. J. Clore. Washington State University, Prosser.

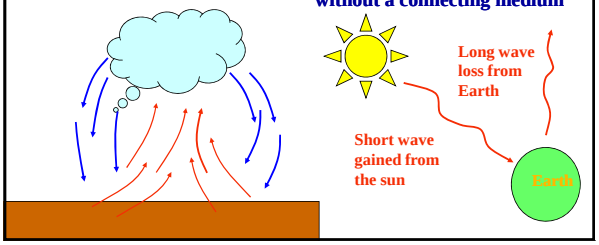
Methods of Heat Transfer

Conduction - from molecule to molecule

Heat Source → Metal bar

Convection - by movement of heated air

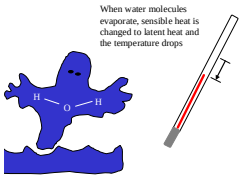
Radiation - energy passing from one object to another without a connecting medium

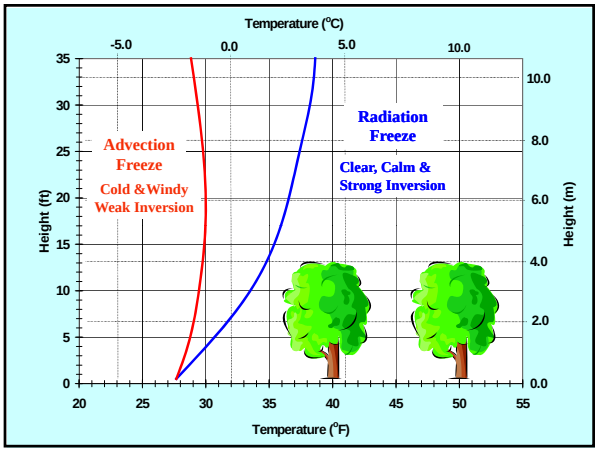


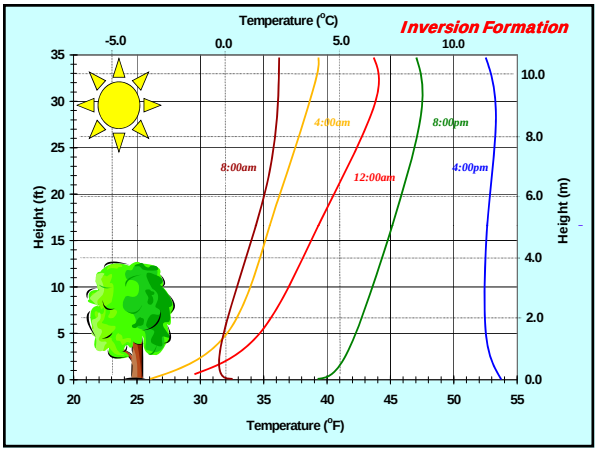
Latent Heat Transfer

Latent Heat - Chemical Heat

Energy is released to the environment as liquid water cools and freezes. Energy is removed from the environment if liquid water evaporates!







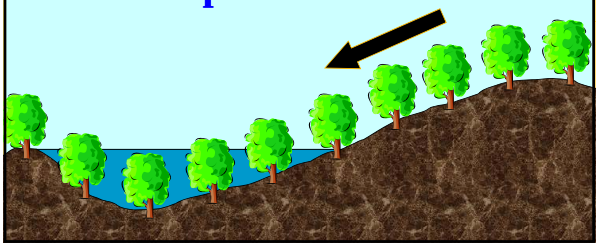
Passive Protection

- ❑ Bacteria Control
- ❑ Site Selection
- ❑ Soil Water Content
- ❑ Ground Cover

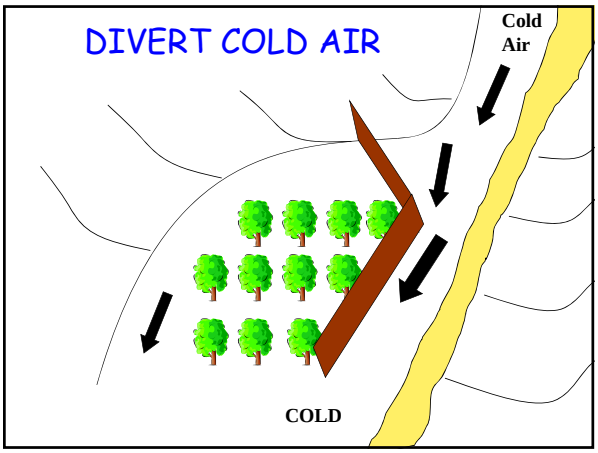
INA Bacteria Control

- ❑ Kill the Bacteria
- ❑ Competitive Bacteria
- ❑ Remove Ground Cover

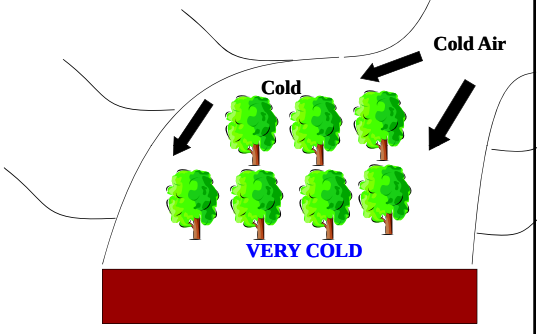
Site Selection
Cold Air Drains to Low Spots



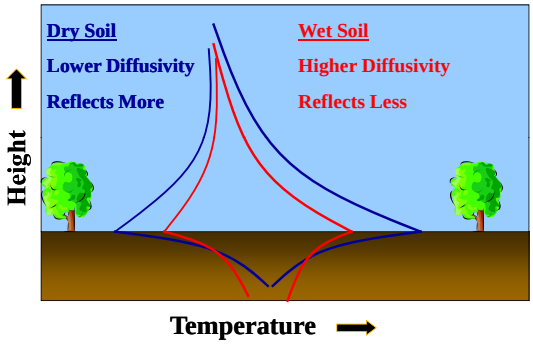
DIVERT COLD AIR



REMOVE COLD-AIR DAMS



SOIL WATER CONTENT



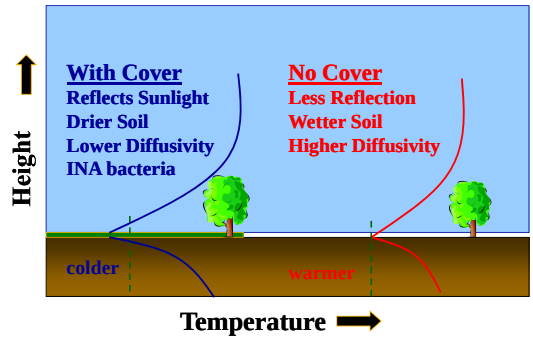
Soil Water Content

If it the soil is dry, apply water 2-3 days prior to a frost night.

Assuming a 50% depletion of available water, typical application depths are:

Course sand	0.24″
Fine sand	0.36″
Loamy sand	0.48″
Sandy loam	0.72″
Light sandy clay loam	0.84″
Sandy clay loam	0.96″
Clay loam	1.08″
Heavy clay	1.20″

COVER CROP



Cover Crop

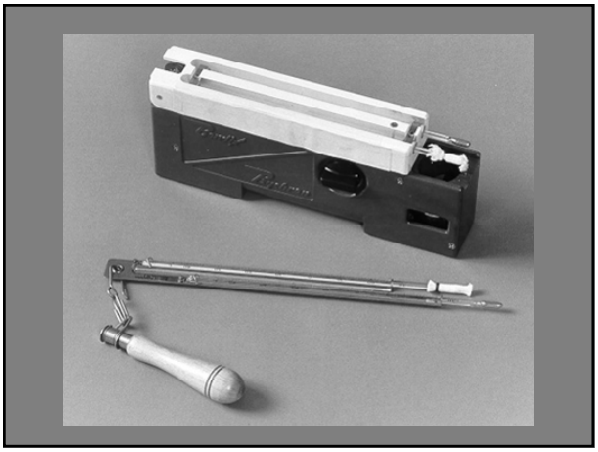
1. If frost is a serious problem, remove cover crop during potential frost periods.
2. Herbicide control is best
3. If mowed, remove residue
4. If cultivated, roll to compact the soil

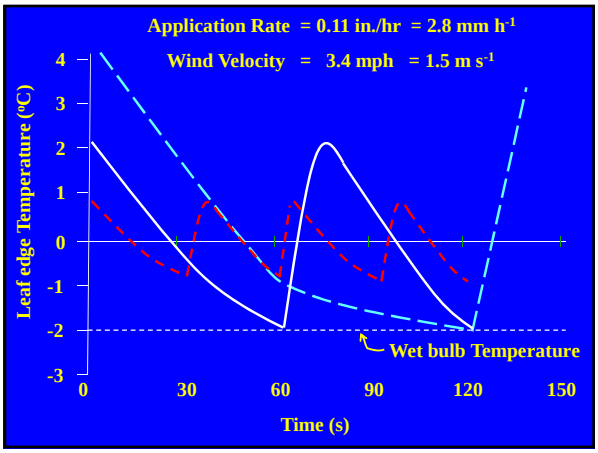
Active Protection

- ❑ Sprinklers
- ❑ Surface Water
- ❑ Wind Machines
- ❑ Helicopters

Sprinklers

- ➢ Heat comes from freezing water
- ➢ Application rate depends on energy loss and the evaporation rate
- ➢ Start when the wet-bulb temperature is above the critical temperature
- ➢ Stop when the wet-bulb temperature is above 32°F (0°C)



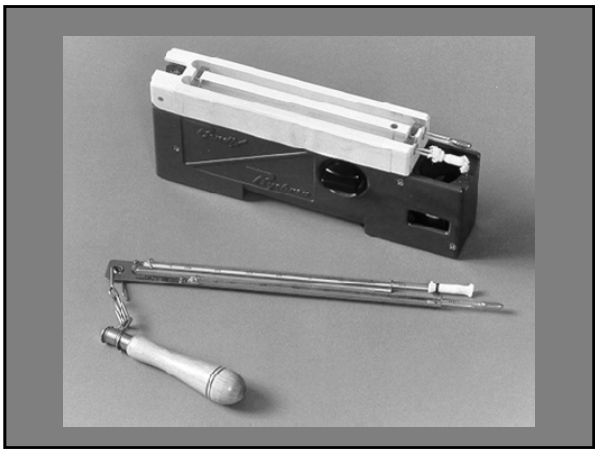


Starting and Stopping

When sprinklers start the air temperature drops to the wet-bulb temperature.

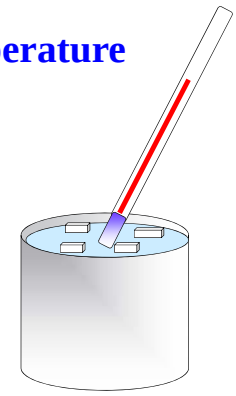
If wetted and not re-wetted, the plants will cool to the wet-bulb temperature.

Start when $T_{wet} > T_{critical}$
Stop when $T_{wet} > 32°F$ (0°C)



Dew point Temperature

Slowly add ice cubes to the water to lower the can temperature. Stir the water with a thermometer while adding the ice cubes to insure the same can and water temperature. When condensation occurs, note the dew point temperature.



Select a wet-bulb equal to the critical damage temperature and select the start and stop air temperature corresponding to the dew-point.

Dew-point	Wet-bulb Temperature (°F)					
°F	23.0	24.8	26.6	28.4	30.2	32.0
32.0						32.0
30.2					30.2	33.3
28.4				28.4	31.3	34.3
26.6			26.6	29.5	32.4	35.4
24.8		24.8	27.5	30.4	33.4	36.3
23.0	23.0	25.7	28.6	31.3	34.3	37.2
21.2	23.9	26.6	29.3	32.2	35.2	38.1
19.4	24.6	27.3	30.2	33.1	36.0	39.0
17.6	25.5	28.2	30.9	33.8	36.7	39.7
15.8	26.1	28.9	31.6	34.5	37.4	40.5

Application Rate

Cooling

68°F (20°C) to 32°F (0°C)

+20 cal/gm

+ 4.14 kJ °C^{-1} L^{-1}

Freezing

at 32°F (0°C)

+80 cal/gm

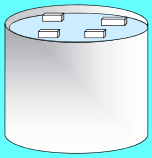
+ 335 kJ L^{-1}

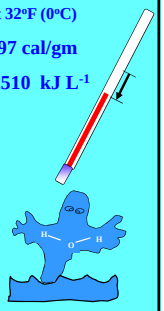
Evaporation

at 32°F (0°C)

597 cal/gm

- 2510 kJ L^{-1}





28

Typical Impact Sprinkler Application Rates Wine Grapes

T_{min}	Wind Speed	30 s	60 s
°F	mph	gpm A^{-1}	gpm A^{-1}
28.9	0.0-1.1	36.0	45.0
26.1	0.0-1.1	49.5	58.5
23.0	0.0-1.1	67.5	76.5
28.9	2.0-3.1	45.0	54.0
26.1	2.0-3.1	58.5	67.5
23.0	2.0-3.1	81.0	90.0

Sprinklers

Impact **Targeted**

Targeted Sprinkler – Estimated Application Rates for Wine Grapes

		Sprinkler Coverage Area (%)		
T_{min}	Wind Speed	100	50	33
°F	mph	gpm A^{-1}	gpm A^{-1}	gpm A^{-1}
28.9	0.0-1.1	36.0	18.0	12.0
26.1	0.0-1.1	49.5	25.0	16.5
23.0	0.0-1.1	67.5	34.0	23.0
28.9	2.0-3.1	45.0	23.0	15.0
26.1	2.0-3.1	58.5	30.0	20.0
23.0	2.0-3.1	81.0	41.0	27.0

Targeted Vs Impact

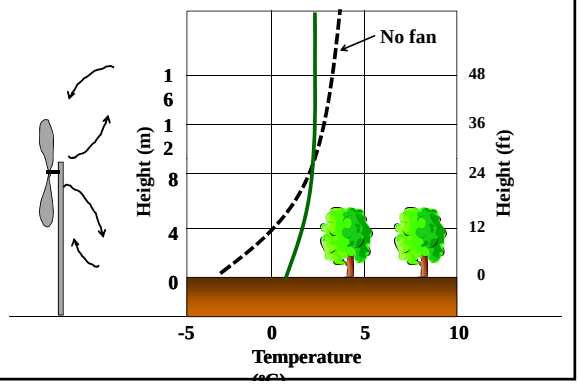
Sprinklers	gpm /Acre
Targeted	15.0
Impact	55.1

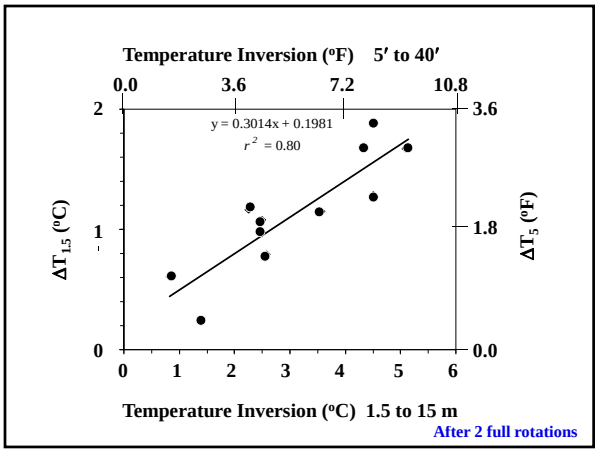
Equal protection at 21.6°F (-5.8°C)

Higher cost and more labor to keep the sprinklers properly oriented.

Fetzer (near Manton)

With Wind Machine





After 2 full rotations

Turn-on Time

When exposed plant temperature nears 32°F (0°C)

Turn-off Time

When exposed plant is above 32°F (0°C).

If the plant or fruit was frozen, operate 1-2 hours longer.