



Cold Protection by Irrigation: Dew Point and Humidity Terminology¹

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Various forms of irrigation have been used for frost and freeze protection for many years. When used properly, water can provide partial or complete cold protection for a number of crops. On the other hand, improper use of water can increase cooling or ice loading and cause greater damage than if no water were used at all. Because water can provide protection in one situation and cause damage in another, it is important to know what principles are involved. To better understand what can happen when using water during a freeze, several commonly used terms need to be understood. With a knowledge of these terms, one can better evaluate the risks and benefits and successfully use irrigation for cold protection.

Heat of fusion - This is the heat that is released when liquid water freezes to solid ice. The amount of heat generated when water freezes is 1200 BTUs/gallon or 80 calories/gram of water frozen. As long as enough water is continuously applied to a plant, the heat generated when water freezes generally keeps the plant at or near 32°F (0°C). This is the principle used by strawberry, fern, or citrus nursery growers when they apply high volumes of water by sprinkler irrigation to protect their plants. At least 0.25 inch/hour or more is required for cold protection. With very low temperatures, low humidity, or high winds, more water must be applied to get adequate protection. Many citrus nurserymen need to apply water at rates of 0.35 inches/hour or higher.

Heat of vaporization - This is the heat lost when water changes from a liquid to water vapor. At 32°F, the heat of vaporization is about 8950 BTUs/gallon or 596 calories/gram of water evaporated. Note that the heat of vaporization is about seven and one-half times greater than the heat of fusion. This means that to maintain a stable situation when both freezing and evaporation occur, for every gallon of water that evaporates, seven and one-half gallons of water need to be frozen to balance out the heat in the grove. Anything that promotes evaporation, such as low humidity and high wind speed, will promote overall cooling.

If the water application rate is high enough on the trunk of a young tree, it will be protected by the ice formation. However, on the edge of and outside of the iced zone, temperatures will not be maintained at 32°F, and those parts will probably be damaged or killed. Hence, usually the tops of young trees or branches above the iced zone are more severely damaged after a freeze.

Humidity - This refers to the amount of water vapor in the air. There are various ways to express humidity, but the most commonly used terms are relative humidity and dew point temperature.

Relative humidity (RH) - This is the percentage or ratio of water vapor in the air in relation to the amount needed to saturate the air at the same

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temperature. Although commonly used, relative humidity is not the best measure of humidity because it depends on the air temperature. Warm air holds more water vapor than cool air. For example, the relative humidity could be 70% at 40°F or 70% at 90°F, but the amount of water vapor in the air would be less at the cooler temperature even though the RH values were identical.

Dew point temperature - This is the temperature at which dew begins to form or the temperature at which water vapor condenses to liquid water. It is also the temperature at which air reaches water vapor saturation. A common example of condensation is the water that forms on the outside of a glass of ice water. This happens because the temperature of the glass surface is lower than the dew point temperature of the ambient air in the room. Hence, some of the water vapor in the surrounding air condenses on the outside of the cold glass.

When referring to cold protection, dew point is one of the better ways to describe the humidity or amount of water vapor in the air. When the dew point is below 32°F, it is often called the frost point because frost can form when the temperature is below freezing. The dew point is important on freeze nights because water vapor in the air can slow the rate of temperature fall. With a relatively high dew point on a cool night, radiant heat losses from a grove are reduced, and the temperature may be expected to fall slowly. But if the dew point is quite low, the temperature may be expected to fall rapidly. Water vapor absorbs infrared radiation. Water droplets or fog are an even more effective radiation absorber than water vapor. Hence, fog can reduce the rate of temperature drop on a frost night.

In addition to affecting the rate of radiation loss, the dew point is often a "basement" temperature, and the air temperature will not go much below it unless drier air moves in. The reason for this is that when dew condenses or ice forms, heat is given off. This heat from condensation is the same as the heat of vaporization (about 8950 BTUs per gallon or 596 calories per gram of water) because vapor is changing to liquid water. This heat release during condensation slows the rate at which the air temperature drops. If dew forms, water vapor is condensed from the air, and the humidity or dew point of that air is lowered. This is the way that the evaporation coil in an air conditioner removes water vapor and dehumidifies the air.

Dew point temperatures are commonly higher on the coasts than they are inland. In the central Florida citrus belt (e.g. near Lake Alfred), dew point temperatures on a moderate frost night can be in the vicinity of 20 to 30°F. On more severe freeze nights, dew point temperatures can be 10°F or lower. For example, in the damaging Christmas, 1983 and January, 1985 freezes, dew point temperatures in Lake Alfred approached 5°F, which are exceedingly low for central Florida.

Dry bulb temperature - This is the temperature of the ambient air. This is the same thing as the normal air temperature read with a grove thermometer.

Wet bulb temperature - This is defined as the lowest temperature to which air can be cooled solely by the addition of water. An example of the wet bulb temperature is the temperature one would feel when coming out of a swimming pool on a windy day. As long as a surface is wet while in the wind, its temperature will drop to the prevailing wet bulb temperature of the air.

The wet bulb temperature is between the dew point and dry bulb temperatures and normally closer to the dry bulb than the dew point temperature. When the air is saturated with water vapor, the relative humidity is 100%, and all three temperatures (dew point, wet bulb, and dry bulb) are equal.

Psychrometer - A psychrometer is a device used to determine atmospheric humidity by the reading of two thermometers, the wet bulb and dry bulb thermometers. The wet bulb thermometer is kept wet by a moistened sleeve. With a psychrometer, one determines how much cooler the wet bulb is than the dry bulb and then calculates humidity by using appropriate graphs or tables. "Psychros" comes from the Greek word meaning "cold," and hence a psychrometer measures humidity by determining how much colder the wet bulb thermometer is than the dry bulb thermometer. An example of a psychrometer is shown in Figure 1.

For an accurate reading, the wet bulb thermometer must have air moving over it. With a sling psychrometer, air flow is created by rotating the two thermometers through the air by hand. With a fan ventilated psychrometer, a fan blows air across the two thermometers. Fan ventilated psychrometers cost more than sling psychrometers, but they are more convenient to operate on freeze nights.

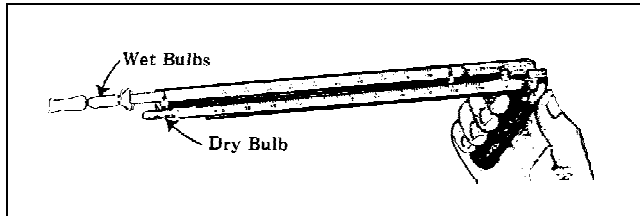


Figure 1. Psychrometer

Sling psychrometers work well at temperatures above freezing, but are more difficult to operate at temperatures below freezing. The reason for this is that at temperatures much below freezing, the water on the wet bulb freezes, releases its heat of fusion, and raises the wet bulb temperature to around 32°F. Eventually, it is possible to get a "frost" wet bulb temperature if one rotates the sling psychrometer long enough. A battery powered fan psychrometer avoids some of the problems of a sling psychrometer because it may take 20 minutes or more to get a valid wet bulb temperature when the air is below freezing. A slightly different chart is used for humidity calculations when the wet bulb sleeve has ice on it.

Wind chill - This refers to the cooling effect of moving air on a warm body and is expressed in terms of the amount of heat lost per unit area per unit of time. Wind chill was developed to estimate heat loss rate from humans or warm blooded organisms. It does not apply to plants or vegetation because they are not warm blooded. In a windy freeze, temperature of a dry leaf is usually fairly close to air temperature. If the leaf is wet and water is not freezing on it, the leaf can theoretically cool to the wet bulb temperature. Even though wind chill does not apply to plants, wind can remove heat from a grove rapidly. Hence, the length of time a grove will be at low temperatures can be longer on a windy night than on a calm one. Thus, more damage can potentially occur during a windy freeze.

Conclusion

Humidity plays an important role in freezes, particularly if one is using water for cold protection. Water is a two-edged sword that can either help or hurt when used during a freeze. An understanding of humidity concepts and water principles can help a person use irrigation for cold protection successfully.