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# Maintain temperatures with evaporative cooling

Physical properties of air
Page 40

System weaknesses
Page 42

2 systems will help you maintain target set point temperatures when a ventilation system is not enough.

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When regular ventilation and shading are not able to keep the greenhouse temperature at the desired set point, additional cooling is needed. Growers can use evaporative cooling as a simple and relatively inexpensive alternative.

The maximum amount of cooling possible with evaporative cooling systems depends on the humidity of the air as well as the initial temperature of the air. Basically, the drier the initial air, the more water can be evaporated into it, and the more the final air temperature will drop. Also, warmer air is able to contain more water vapor compared to colder air.

Two evaporative-cooling systems are commonly used in greenhouses: pad-and-fan and fog.

## Pad-and-fan systems

Pad-and-fan systems are part of a greenhouse's mechanical ventilation system. For pad-and-fan systems, an evaporative-cooling pad is installed in the ventilation opening, ensuring that all incoming ventilation air travels through the pads before it enters the greenhouse environment. The pads are typically made of a corrugated material glued together to allow air to pass through them while ensuring a maximum contact surface between the air and the wet pad material.

Water is pumped to the top of the pads and released through small openings along the entire length of the supply pipe. These openings are typically pointed upward to prevent clogging by any debris (installing a filter system is recommended). A cover is used to channel the water downward onto the top of the pads after it is released from the openings. The opening spacing is designed so that the entire pad area wets evenly without allowing patches to remain dry.

At the bottom of the pads, excess water is collected and returned to a sump tank to be reused. The sump tank is outfitted with a float valve allowing for make-up water to be added.

### Reducing cooling efficiency

Since a portion of the recirculating water is lost through evaporation, the salt concentration in the remaining water increases over time. To prevent an excessive salt concentration from creating salt crystals on the pad material (reducing pad efficiency), it is a common practice to continuously bleed off approximately 10 percent of the returning water to a designated drain. During

**Evaporative cooling pads are installed along the inside of a greenhouse ventilation inlet opening.**

## Physical properties of air

To use a psychrometric chart to help determine the maximum temperature drop resulting from the operation of an evaporative cooling system, it is important to know a few key physical properties of air.

Dry bulb temperature (Tdb, F). Air temperature measured with a regular (mercury) thermometer.

Wet bulb temperature (Twb, F). Air temperature measured when the sensing tip is kept moist (e.g., with a wick connected to a water reservoir) while the (mercury) thermometer is moved through the air rapidly.

Dew point temperature (Td, F). Air temperature at which condensation occurs when moist air is cooled.

Relative humidity (RH, %). Indicates the degree of saturation (with water vapor).

Humidity ratio (lb/lb). Represents the mass of water vapor evaporated into a unit mass of dry air.

Enthalpy (btu:lb). Indicates the energy content of a unit mass of air.

Specific volume ($ft^3$/lb). Indicates the volume of a unit mass of dry air (equivalent to the inverse of the air density).

summer, it is common to run the pads "dry" during the nighttime hours to prevent algae build-up that can also reduce pad efficiency.

As the cooled (and humidified) air exits the pad and moves through the greenhouse toward the exhaust fans, it picks up heat from the greenhouse environment. Therefore, pad-and-fan systems experience a temperature gradient between the inlet (pad) and the outlet (fan) side of the greenhouse. In properly designed systems, this temperature gradient is minimal, providing all plants with similar conditions. Temperature gradients of 7°F-10°F are not uncommon.

### Pad size and flow rates

The required evaporative pad area depends on the pad thickness. For the typical, vertically mounted 4-inch-thick pads, the required area (in square feet) can be calculated by dividing the total greenhouse ventilation fan capacity (in cubic feet per minute) by the number 250 (the recommended air velocity through the pad).

For 6-inch-thick pads, the fan capacity should he divided by the number 350. The recommended minimum pump capacity is 0.5 and 0.8 gallons per minute per linear foot of pad for the 4- and 6-inch-thick pads, respectively. The recommended minimum sump tank capacity is 0.8 and 1 gallon per square feet of pad area for 4- and 6-inch pads, respectively. For evaporative cooling pads, the estimated maximum water usage can be as high as 10-12 gallons per day per square foot of pad area.

## Fog systems

A fog system is often used in greenhouses with natural-ventilation systems. Natural-ventilation systems rely only on opening and closing strategically placed vents and do not use mechanical fans. Natural-ventilation systems generally are not able to overcome the additional airflow resistance created by evaporative cooling pads.

The nozzles of a fog system can be installed throughout the greenhouse, resulting in a more uniform cooling pattern compared to a pad-and-fan system. The recommended spacing is approximately one nozzle for every 50-100 square feet of growing area.

### Water properties

The water pressure used in greenhouse fog systems is very high (500 pounds per square inch and higher) to produce very fine droplets that evaporate before they reach plant surfaces. The water usage per nozzle is small, approximately 1-1.2 gallons per hour.

The water needs to be free of any impurities to prevent clogging of the small nozzle openings. As a result, water treatment (filtration and purification) and a high-pressure pump are needed. The usually small-diameter supply lines should be able to withstand the high water pressure.

### Minimize noise

Fog systems, in combination with natural ventilation, produce little noise compared to mechanical ventilations systems. This can be an important benefit for employees and customers who may be inside the greenhouses.

### Determining cooling efficiency

The maximum amount of cooling provided by evaporative-cooling systems depends on the initial temperature and humidity of the air. You can measure these parameters easily with a standard thermometer (measuring the dry-bulb temperature) and a relative humidity sensor. With these measurements, you can use a psychrometric chart (on Page 40) to determine the corresponding wet bulb temperature at the maximum possible relative humidity (100 percent).

Once you know the corresponding wet bulb temperature, you can calculate the difference (also called the wet bulb depression) that indicates the theoretical temperature drop provided by an evaporative-cooling system. Since few engineered systems are 100-percent efficient, the actual temperature drop is more likely to be on the order of 80 percent of the theoretical wet bulb depression.

## System weaknesses: Pad vs. fog

When evaporative-cooling pad systems appear to perform below expectations, it is tempting to assume that an increase in the ventilation rate would improve performance. However, increased ventilation rates result in increased air speeds through the cooling pads, reducing the time allowed for evaporation. As a result, the overall system efficiency can be reduced while water usage increases.

In addition, increased ventilation rates may result in a decrease in temperature and humidity uniformity throughout the growing area. A similar situation can occur with fog systems. Installing more fog nozzles may not necessarily result in additional cooling capacity, while system inputs (installation cost and water usage) increase.

In general, fog systems are able to provide more uniform cooling throughout the growing area and this may be an important consideration for some greenhouses. It should be clear that, like many other greenhouse systems, the design and control strategy for evaporative-cooling systems requires some thought and attention.

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