GROWERTALKS

Features

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# 6 Cool Considerations

*Joli A. Hohenstein*

Your greenhouse is designed to grab solar radiation and create the environment for the most productive growth of your plants. But even the most modern greenhouses need to cope with temperature rises in the middle of the day due to the greenhouse effect and summer's sizzling rays. And that's where heat gain removal or avoidance comes in.

*pictured: Circulation fans must be designed with high velocities that can cover the entire greenhouse.*

Maintaining the right temperature in the greenhouse is obviously important. High temperatures can cause reduced stem strength, reduced flower mass, reduced leaf quantity and deformed shapes, delayed flowering, flower bud abortion and reduced growth rate. Limiting too-high temperatures in greenhouses is accomplished with natural ventilation and mechanical ventilation where heated air is exchanged with outside air. With enough air exchange, the greenhouse temperature can approach the outside temperature.

But airflow quantity isn't the only important factor; air distribution is equally important. Greenhouses vary in distance from vent to center of greenhouse, height—which affects buoyancy—orientation to prevailing winds, vent area, etc. It's important to try to get airflow uniformly distributed over the crop and minimize hot spots. When airflow and air distribution don't cool enough, water evaporation comes in. Plants are naturally evaporative coolers and additional cooling can be accomplished with wetted air inlet pads and misting. When these techniques aren't enough, then solar heat gain avoidance in the form of shading comes in.

While temperature is important, so is humidity, or the amount of water vapor in the air. High humidity levels are harmful to some plants because they can't transpire. Transpiration is important for both cooling and moving nutrients from roots to shoots. On the other hand, when the air is too dry, plants will transpire more

rapidly, often losing a great deal of moisture. In the case of vegetable production, with too-rapid transpiration, nutrients, such as calcium, cannot migrate into fruits and this leads to damage.

Given the challenges of overheating and the dynamic nature of greenhouse ventilation and control, it can be hard to know where to start. Boiling it down to a few key considerations can help jump-start your decision.

Here are six cool considerations for cooling:

**1. Target your temperature |** First, decide the maximum target air temperature for your crop. For example, you may want to shoot for 7F above the outside air temperature. (Factors such as size and location can and should impact this.) If you want a 4F rise, you'll need to add 75% more fans for example, says Acme's Dave Roadruck.

**2. Get enough airflow |** An appropriate air pattern within a greenhouse is one of the biggest keys to efficient cooling. Circulation fans must be designed with high velocities that can cover the entire greenhouse. To do this, come up with an estimated airflow, or the number of cubic feet per minute your fans have to move. Dave suggests starting with 9.5 cu. ft. per minute (CFM) per square foot of flow space. The basic airflow is estimated from the number of BTUs hitting the surface of the U.S. This varies by geography, but that number is a starting point for average locations in the U.S. And that figure is based on the worst part of the season (summer), so it should account for virtually any time of the year. Remember, distance matters. If you have a short distance between the fan and the cooling pad and the inlet, you're going to be penalized because of air velocity or the lack thereof. Typically, the recommendation is for more than 100 ft., says Dave. If the fan to inlet distance is down to 50 ft., use a 1.4 factor.

**3. Distribute the airflow (horizontally and vertically) |** If you have a greenhouse with plants on one level, then only cool that space. If you have hanging plants or displays up into the gables, or you're growing tall plants like tomatoes, you need to cool the upper reaches of the greenhouse, including the gables. Know what your crop demands.

And remember: The numbers discussed here are based on greenhouses full of plants. Plants create their own cooling, so you can't measure an empty greenhouse and get the same calculations—or expect to get the same results.

**4. Evaporative cooling can be effective anywhere |** Evaporative cooling is a process that reduces air temperature by evaporation of water into the airstream. Simply put, it's the temperature that comes out of the air every time you add moisture in. If you spray a person with a water hose and turn a fan on them, they'll feel cool. That's evaporative cooling at work. "You can get evaporative cooling effects anywhere, even in Canada," says Dave. "The fact that the humidity goes down during the middle of the day is what evaporative cooling is based on." If it's 100F (37C) in the middle of the day but 70F (21C) at night, an evaporative cooling system can chill the air around 70% of that difference.

**5. Chilling is worth considering (refrigeration) |** The local environmental conditions will help in determining the type of cooling system. If the climate is a dry type, evaporative cooling works very efficiently. If the climate is more humid, you may want to consider cooling the greenhouse with refrigeration systems. Be

sure to look at greenhouse orientation when installing, says JD Wasir of KoolJet. A cooling system inside and outside the greenhouse can constrain the amount of sunshine. The shade from the indoor cooling units can reduce the growth of some of the plants. Depending on the greenhouse placement, a packaged refrigeration system or a split-type cooling unit can be used. Always check your local regulations; for example, if city water isn't allowed for HVAC systems, you'll need to use air-cooled rather than water-cooled refrigeration systems.

Another benefit: Chilled water for irrigation improves yield. "For some plants, it's proven that there is significant increment in the yield, if cold water is used," says JD. "Depending on the amount of usage and degree of heat, hot water can also be generated from a refrigeration system itself or de-super heaters."

If there's a requirement for hot water in the greenhouse, it can be generated from the mechanical refrigeration systems by using water-cooled condensers. Something else that can impact irrigation: Shading, since it removes evapotranspiration potential, a factor that describes both evaporation (from wetted surfaces) and transpiration (from leaf surfaces). "It's possible to reduce water consumption by half with effective shading," says Svensson's Kurt Parbst. Shading is most effective when done evenly with porous materials that breathe, so you don't have to leave gaps that impact both crop uniformity and labor costs.

**6. Using shade can save energy costs both in cooling and heating |** Shading is used to control heat stress on greenhouse occupants (plants or people) after ventilation and cooling options have been exhausted, as shading decreases light available to the crop. It's important to avoid creating hot, dark conditions. Two of the most common mistakes in shade selection are over-shading and choosing the wrong type of shade. Select and operate based on plant productivity, not human comfort. High light and lower temperatures generally lead to the best-quality growth, so shading materials should be efficient. "Efficiency in shading means the amount of shading that comes from reflection rather than absorption," said Kurt. Absorbing materials (black) are low efficiency, as they re-radiate heat to the crop without contributing to photosynthesis. High-efficiency materials remain highly reflective over many years by resisting degradation and dust accumulation.

Elevation, feet above sea level

| feet | Under 1000 | 1000 | 2000 | 3000 | 4000 | 5000 | 6000 | 7000 | 8000 |
|---|---|---|---|---|---|---|---|---|---|
| F Elev(e) | 1.00 | 1.04 | 1.08 | 1.12 | 1.16 | 1.20 | 1.25 | 1.30 | 1.36 |

Maximum Interior Light Intensity, foot candles

| FC | 5000 | 5500 | 6000 | 6500 | 7000 | 7500 | 8000 | 9000 | 10,000 |
|---|---|---|---|---|---|---|---|---|---|
| F Light(l) | 1.00 | 1.10 | 1.20 | 1.30 | 1.40 | 1.50 | 1.60 | 1.80 | 2.00 |

House Temperature above Outdoor Temperature °F

| °F | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| F Winter(w) | .83 | .88 | .94 | 1.00 | 1.07 | 1.15 | 1.25 | 1.37 | 1.50 | 1.67 |

Inlet to Fan Temperature Variation, T °F

| °F | 10 | 9 | 8 | 7 | 6 | 5 | 4 |
|---|---|---|---|---|---|---|---|
| F Temp (t) | .70 | .78 | .88 | 1.00 | 1.17 | 1.40 | 1.75 |

Inlet to Fan Distance, feet

| feet | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 |
|---|---|---|---|---|---|---|---|---|
| F Vel (v) | 2.24 | 2.00 | 1.83 | 1.69 | 1.58 | 1.49 | 1.41 | 1.35 |

| feet | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 |
|---|---|---|---|---|---|---|---|---|---|
| F Vel (v) | 1.29 | 1.24 | 1.20 | 1.15 | 1.12 | 1.08 | 1.05 | 1.02 | 1.00 |

*Many factors go into sizing and selecting the right cooling and ventilation equipment for your greenhouse. These tables will make it easier for you to find the numbers that best fit your facility. Tables courtesy Acme Engineering & Manufacturing*

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An average greenhouse stands at about 5,000 foot candles. If you increase light 50%, says Dave, you'll need to install 50% more fans in high-light areas like Texas or Arizona, for example. Shade cloth can impact that and eliminate some of the foot candles coming in. In fact, shade selection should be made based on light

transmission, says Kurt. You could look at it in terms of instantaneous (light intensity) or cumulative (daily light integral) or both. Select a fixed (non-moving) shade based on a cumulative light review. (Will the crop receive enough light during the important market months to grow fast and full enough? Light availability is different in the winter and late spring/summer.) Select a retractable shade based on instantaneous light readings. (Can the shade effectively help hit the light targets that prevent damage during the brightest hours of the day? In general, you can use a retractable shade to satisfy cumulative light needs simply by adjusting the length of time it's deployed.) The latest developments in shading create a high-grade diffusion or a broad scattering of light. Highly diffused light softens the intensity and temperature on the uppermost plant surfaces. This light softening not only allows for better distribution of light over the plant surface area, but also may let a grower select a shade with high-light transmission.

Taking all of these factors into account, plus looking at light, air, dry bulb versus wet bulb, greenhouse orientation, location and more can overwhelm even the most advanced growers. But by starting with some best practices for cooling, you can approach the seemingly insurmountable task smartly and successfully. In other words, just chill out! **GT**

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