WHITE PAPER

UNDERSTANDING THE UPS AND DOWNS OF HUMIDITY MANAGEMENT IN PLANT GROWTH CHAMBERS

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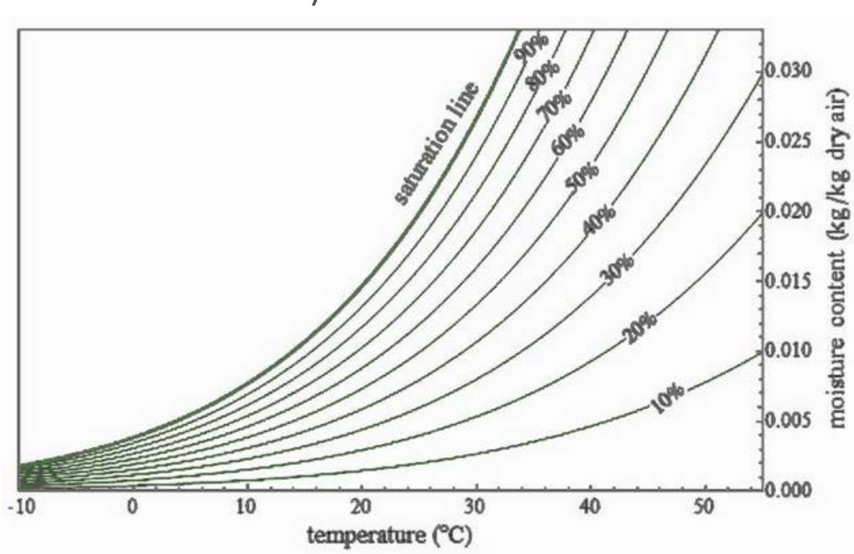
Abstract

Plant growth chambers present challenges unique in the field of environmental simulation. Understanding the effects of temperature, airflow, and radiant lighting on humidity is key to successfully controlling a humidified environment tailored for specific plant growth applications.

Relative Humidity

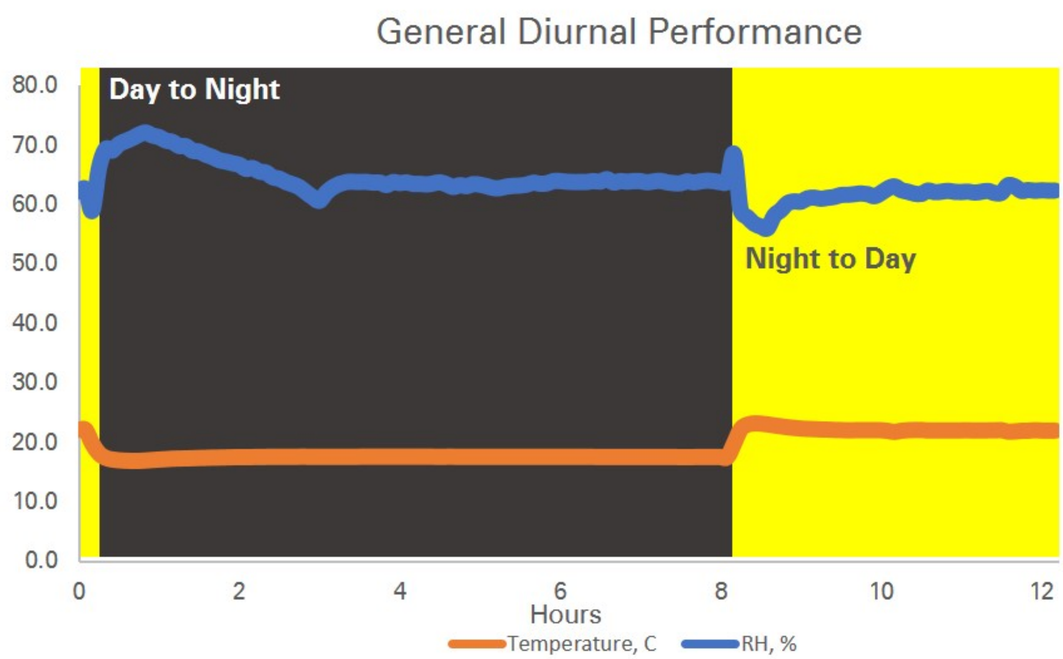
Relative humidity (RH) is a term that refers to how much water air can carry at a specific temperature, with 100% being the maximum. The higher the temperature, the more water it can carry at a given relative humidity level. For example, 80% RH at 37°C involves more than twice the amount of water (absolute humidity) than 20°C air at the same RH level:

Psychrometric Chart



The Impact of Radiant Heat

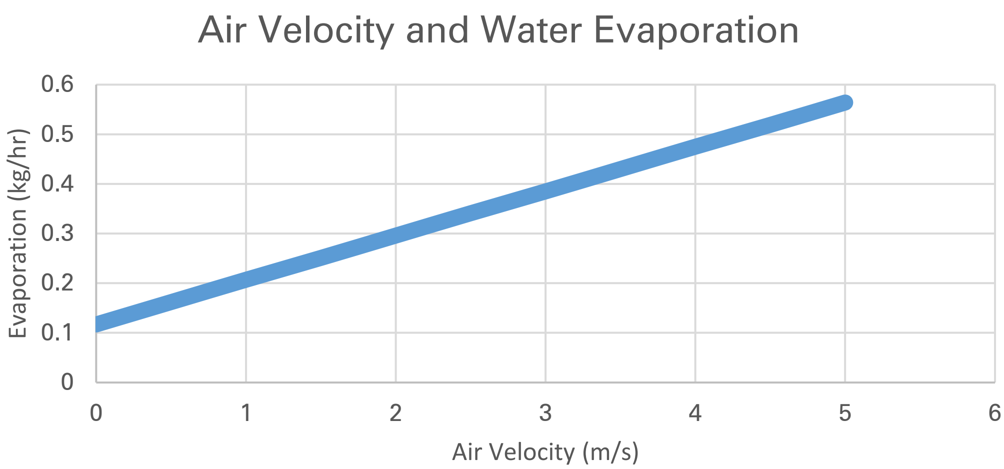
Grow lights, particularly at higher intensities, create radiant heat that raises air temperature. Plant chambers use active cooling (refrigeration) to remove this lamp-generated heat and maintain temperature setpoint. During the heat removal process, water naturally condenses from the air onto the colder surfaces of the refrigeration system. This lost moisture must be replaced by the chamber humidification system to maintain a constant chamber RH level. Turning off lights, as during a simulated day to night transition, immediately eliminates this radiant heat source, reducing the impact of active cooling. As a result, moisture removal slows, causing a short-term increase in chamber RH levels. When the lights are turned back on, air temperature rises and (with no change in total moisture content) the relative humidity level drops. This phenomenon closely mimics the same effect in nature, where dropping nighttime air and surface temperatures cause RH levels to spike, resulting in the formation of dew on grass and foliage, followed by an initial daytime RH drop, until rising surface and air temperatures re-evaporate surface water.



Selecting low-heat light sources such as LED can help reduce the effect of this diurnal phenomenon. But since no technology is 100% efficient at converting electrical energy into light, every light source produces some heat, with related evaporative effects.

The Impact of Airflow

Internal water sources, such as water pans, plant leaves (through respiration), or open media further complicate humidity management. Airflow over these sources evaporates surface water, raising humidity levels.



Evaporation calculated over 1m^2 area, at 0.0147 max saturation humidity ratio (kg H_2O/Kg dry air), and 0.01 initial humidity ratio

At a given airflow level and water and air temperatures, the larger the wetted surface area, the more water evaporation will occur. This evaporation in-turn raises the chamber humidity level. As is the case with day to night transitions, plant growth units need to have a dehumidification system in place to counter evaporative humidification and retain control of chamber RH levels. If the quantity of open water in the chamber is high enough, commercially available dehumidification systems may not be able to successfully control humidity below very high levels.

Caron's Approach

All Caron chambers with optional humidity control feature light to medium-duty dehumidification employing ambient air systems for smaller chambers, and refrigeration coil-based systems for larger ones. Higher moisture volume removal, however, may require the additional capacity of an external column dryer (dry air source required).

To provide guidance on expected performance, Caron has conducted testing using several sets of common applications setpoints.

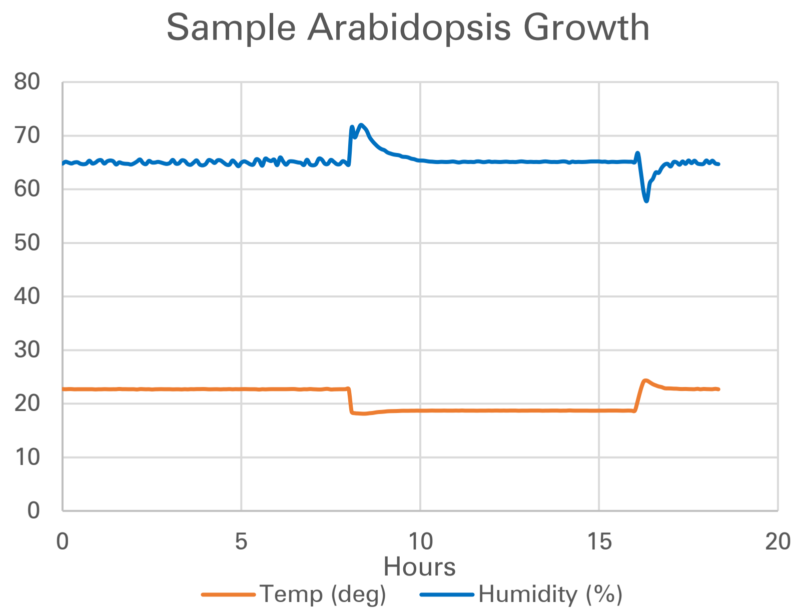
Example 1: Arabidopsis

This genomics reference organism is typically grown under the following conditions:

- Day: Temperature 22°C, humidity 65%, 200 µmole/m^2/s of light
- Night: Temperature 18°C, humidity 65%, lights off

Testing was performed in a 50 cu.ft (1,416L) Caron double-door chamber, with an estimated 3.8 ft^2 (0.107 m^2) of exposed saturated soil.

The graph below starts in Day cycle, changes to Night cycle at 8 hours, and then switches back to Day cycle at 16 hours:



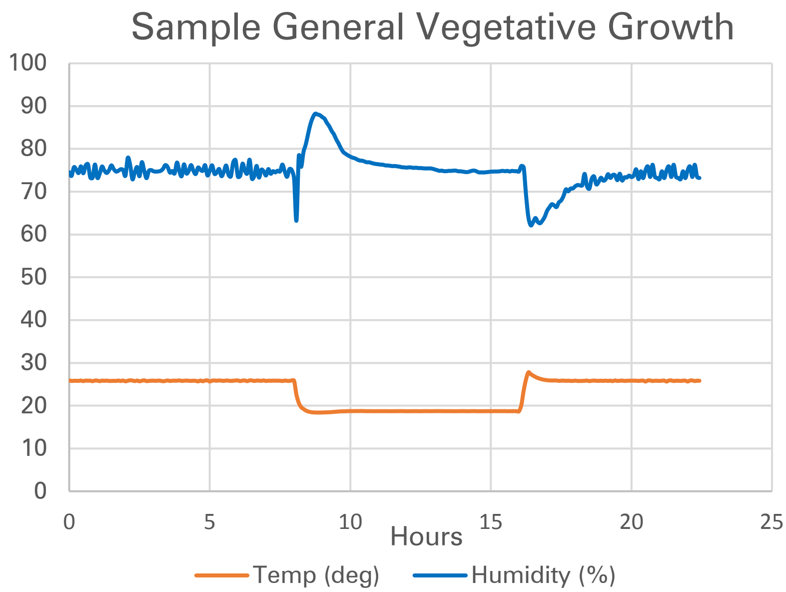
Test data demonstrates that humidity recovers to setpoint within two hours of a Day to Night transition, and one hour when moving from Night back to Day.

Example 2: General Vegetative Growth

This test is representative of both food crops and ornamentals that produce substantial biomass, requiring high light levels, slightly elevated Day temperature and Day/Night temperature differential, and increased watering frequency. These factors make general vegetative more challenging for RH management than Arabidopsis. Generic test criteria for this type of application are:

- Day: Temperature 25°C, humidity 75%, 470 µmole/m^2/s of light
- Night: Temperature 18°C, humidity 75%, lights off

Testing was performed in a 50 cu.ft (1,416L) Caron double-door chamber, with an estimated 7.6 ft^2 (0.215 m^2) of exposed saturated soil:



As in Example 1, Day to Night RH recovery took approximately two hours. Night to Day RH recovery was also around two hours.

Limitations on use of standard RH removal solutions include setting RH night setpoint below day setpoint, seeking extremely rapid diurnal RH transitions, use of trays with standing water within the chamber, very high plant watering volume/frequency, or transitions associated with highly elevated (tropical) temperature levels. If your application incorporates these limiting factors or is generally dissimilar to the two examples provided above, contact Caron for additional guidance before selecting or accessorizing a chamber.

Conclusions

Multiple environmental variables, including radiant heat, internal evaporation, and diurnal cycling, complicate maintaining relative humidity setpoints within plant growth chambers. No one technical solution will accommodate all potential applications. Understanding the key technical factors involved and determining up-front whether target growth parameters are outside the selected chamber performance envelope is an essential step to successfully controlling relative humidity during the growth process.

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