Greenhouse Humidity Control

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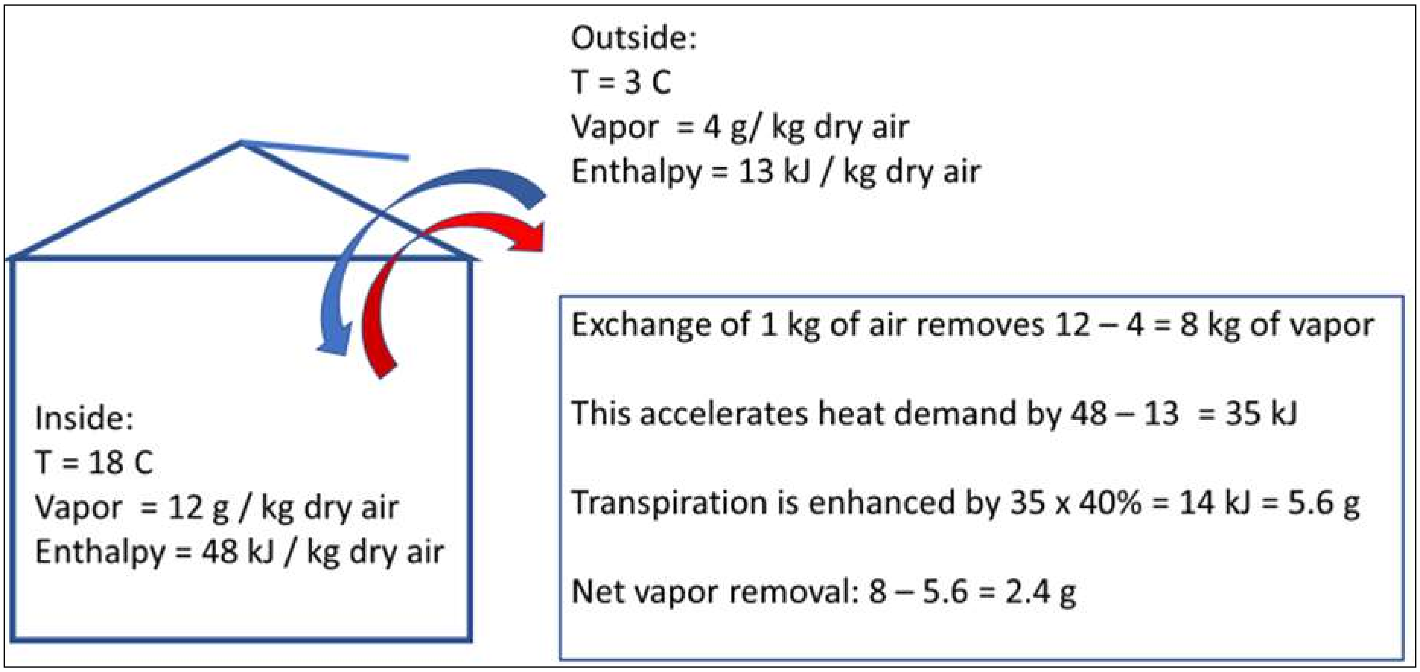

Figure 1. Water vapor removal efficiency via ventilation.

The best defense against fungal infection for high-value, susceptible greenhouse crops is to create environmental conditions that promote a healthy, dry crop that is also hostile to fungal proliferation. This means controlling temperature and humidity such that water is not accumulating on the surface of the plant tissue. Ideal conditions are those where the vapor pressure deficit is sufficiently high for water vapor to leave the foliage and enter the air, avoid dew formation at all times, and avoid water dripping/splashing on foliage.

The challenging hours occur when the sun goes down. A cooler night sky is the driver for glazing to become cold and for plants to radiate to the cooler glazing which results in the foliage reaching temperatures below the green-

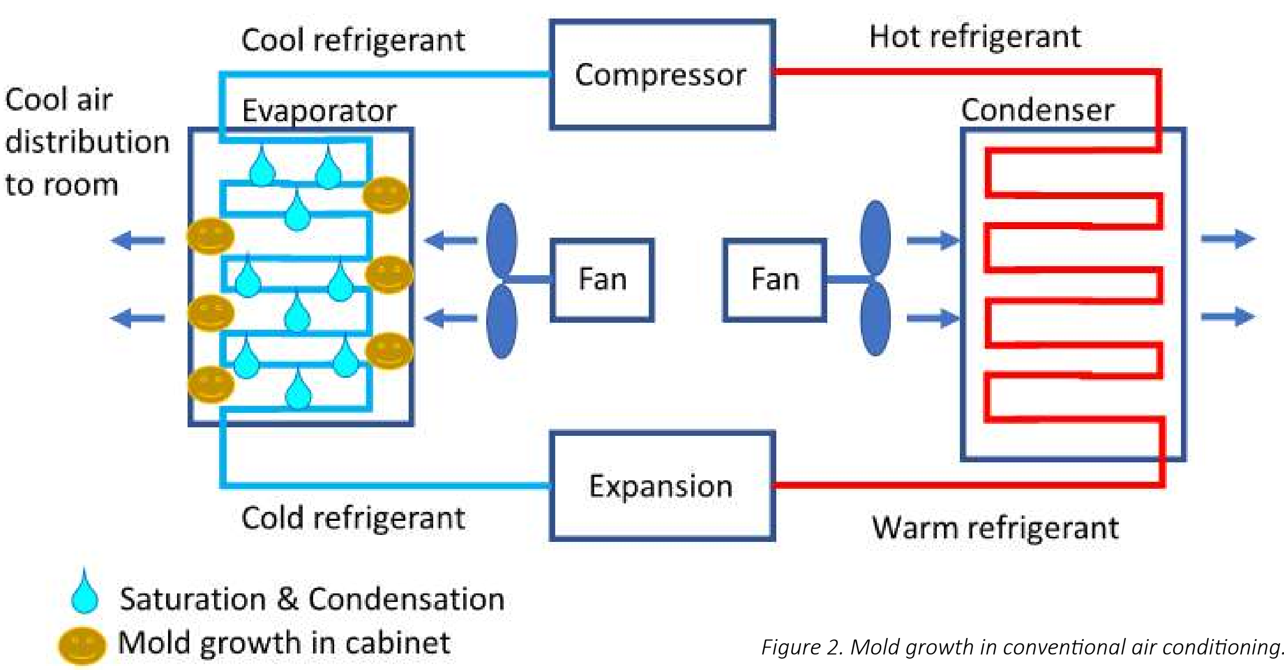

Figure 2. Mold growth in conventional air conditioning.

house air temperature. When the glazing/covering or the foliage reaches the dew point, wetness will occur. Wet glazing or screens can drip onto the crops. A water film from dripping or condensation is the pathway for mold spores to infect plant tissue.

Effective strategies for avoiding dew point conditions are to utilize overhead screens/ curtains, which will slow plant radiation cooling, and to actively dehumidify the air using one of three techniques: ventilation, condensation, or desiccant dehumidification.

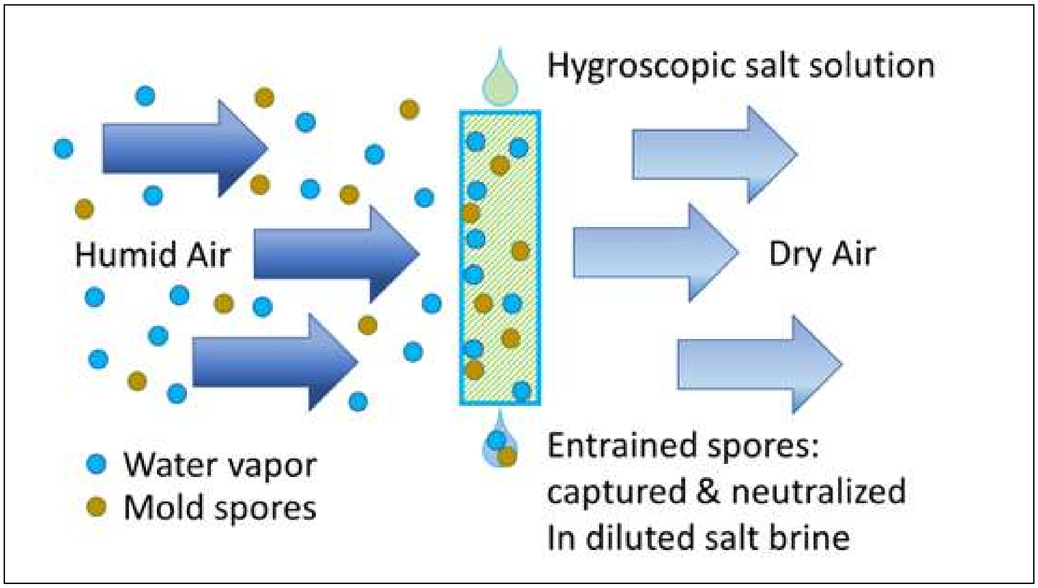

Figure 3. Spore filtering and entrainment in the pads.

Ventilation is the most common tactic, but it offers the lowest level of control/effectiveness and is the most energy intensive. Air is heated so that it can hold more water vapor, but when the upper limit for both temperature and humidity are ultimately reached, indoor air is exchanged with cooler, drier outdoor air with either vents or exhaust fans. When ventilation is used, the cooling that is brought in must be compensated with heating to maintain temperature. Interestingly, heating, especially when delivered beneath the crop, induces the plant to transpire. In fact, about 40% of the energy that is delivered beneath the canopy to help to control humidity is immediately converted by the plant into water vapor. So, there is an escalating relationship or continuous cycle of ventilating, heating, and resulting transpiration (See Figure 1: Net water removal with Ventilation). This makes ventilation an energy-intensive method and creates the limitations of humidity levels that can be achieved. Further, this method creates a continuous cycle of overall rising and falling temperature profile as well as non-uniformity of temperature related to the air inlet locations.

Condensation happens on the underside of a cold roof. Single-paned glass greenhouses of yesterday were energy intensive, but rather dry, owing to a great area of condensing/dehumidifying surface. The greenhouses that we use today with multiple wall glazing and screens/curtains dehumidify less, owing to warmer interior surface, and we struggle more to control humidity. Condensation is also what happens inside conventional, refrigerant and compressor-based air conditioning: Air is drawn across a cold refrigerant coil and water condenses and drains away. The challenges with this method are that saturated conditions are created on the building envelope or, with the case of air conditioning, inside the cabinet. Saturated conditions (100% relative humidity) combined with a food source like dust-borne nutrients, allows bacterial and mold to flourish and then be distributed throughout the canopy on the air stream travelling along surfaces or across the coils (See Figure 2: Saturation within Fan Coils). This, along with the electric energy intensity of operating a refrigerant compressor, has limited the adoption of conventional air conditioning and heat pumps.

Desiccant dehumidification employs a chemical method whereby water vapor is absorbed by hygroscopic material such as a salt. Energy is then required to regenerate or dry the desiccant. The Israeli company, Agam, has created a

Figure 4. A picture of dehumidification units

synergistic, liquid desiccant dehumidification system that works with the knowledge that convection and transpiration are linked and addresses the greenhouse/plant dynamic in a matter that is very energy efficient. The energy that is needed for desiccant regeneration is borrowed, and the latent heat that is utilized in both the dehumidification and desiccant regeneration process are supplied to the growing zone, offsetting heating demand. This method reduces annual energy consumption needed for heating by about 60% compared with the heating and venting method. The technique provides a greater level of humidity control and by treating a closed environment at night leads to a much more uniform temperature and humidity profile.

Typically, heating is by far the largest energy related expense in greenhouses. The primary objective is to control humidity such that dangerous conditions are avoided. Of course, other practical strategies for avoiding fungal infection such as using resistant strains and practicing good housekeeping should be maintained. A significant benefit to utilizing a liquid salt solution is that the interaction at the water vapor/liquid salt interface also collects and neutralizes airborne mold spores effectively cleaning the air. The system operates during the night hours and can act in modes that provide primary heating, dehumidify with minimal heating, and provide simultaneous cooling and dehumidification when coupled with an external cold-water source should night temperatures be too great during the summer.

Actively treating a closed greenhouse at night leads to a smoother temperature profile which also helps avoid problematic cold spots, which can become wet. Uniformity is accomplished by creating a vertical airflow circuit where buoyant air travels across the top of the canopy and reverses direction against a far wall and travels near the floor to be recirculated back through the machine.

Utilities are becoming aware of the large energy savings potential of this technology and are creating incentives for more rapid adoption in an effort to reach their energy efficiency and carbon emissions goals. While energy efficiency helps growers to be more competitive from an operational costs perspective, most users find that the quality and productivity benefits associated with the avoidance of infection and loss provide and even greater economic incentive. ■