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FEATURES

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VPD, Temperature & Everbearing Strawberries

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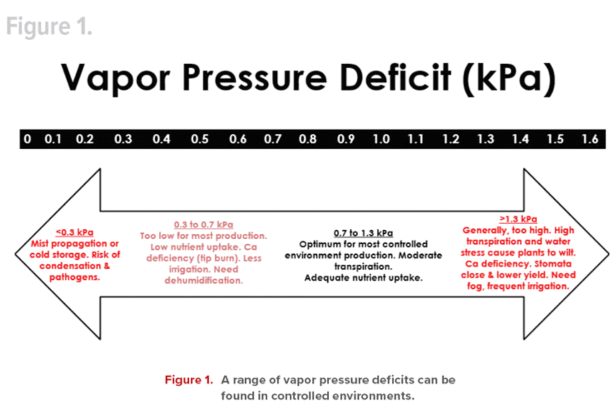
Vapor pressure deficit (VPD) is increasingly monitored by greenhouse and indoor growers because modern environmental control systems can display it in real time, allowing growers to adjust humidity, ventilation and temperature to maintain specific VPD targets. The underlying assumption is straightforward: If VPD influences transpiration, nutrient uptake, disease incidence and photosynthesis, then optimizing VPD should improve crop performance, quality and ultimately yield.

Figure 1. A range of vapor pressure deficits can be found in controlled environments.



While the physiological importance of VPD is well established, our recent research at Michigan State University aimed to determine the influence of greenhouse VPD and air temperature on physiological performance, berry quality and yield of three everbearing strawberry cultivars.

Understanding why VPD matters

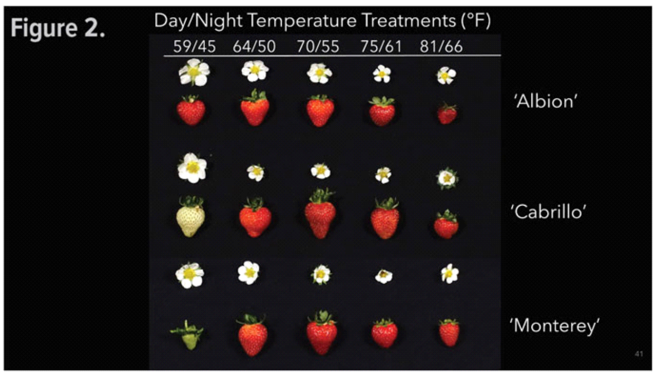
VPD describes the difference between the amount of moisture currently in the air and the maximum amount of moisture the air can hold at saturation. Unlike relative humidity, which varies directly with temperature, VPD is a more precise indicator of atmospheric evaporative demand and the primary driver of plant water loss through transpiration. When VPD is low, the air is nearly saturated with water vapor and transpiration slows. When VPD is high, plants lose water more rapidly through their leaves. Importantly, transpiration is more than simply water loss. It drives the movement of water and nutrients from the roots to shoots, leaves and fruits, helps cool the leaves, and supports photosynthesis.

Greenhouse VPD ranges

Very low VPD (<0.3 kPa). In this situation, water vapor is at or near saturation. This low VPD occurs when the RH is above 85% at 63F, 88% at 68F and 90% at 73F. This environment is desirable only for slow-drying conditions, such as during initial cuttings propagation or cold storage of plant material. When plants are grown at a very low VPD, there's little movement of water through the plant, and thus, little uptake of nutrients from the substrate (Figure 1). Leaves remain wet for extended periods and the substrate dries very slowly, thereby increasing the virulence of plant pathogens.

Low VPD (0.3 to 0.7 kPa). This is the minimum desirable VPD for most production applications. This VPD range occurs when the RH is 64% to 85% at 63F, 70% to 88% at 68F and 75% to 90% at 73F. The gradient that exists between leaves (which are practically saturated with water) and the air means that plants transpire at a moderately slow rate. This VPD range can be desirable during propagation once young plants have developed an initial root system (Figure 1). Leaves don't remain wet for long and there's modest uptake of water and nutrients from the substrate. If strawberries are exposed to low VPDs during the day and night, they become susceptible to calcium deficiency, which appears as tip burn on the leaves.

Moderate VPD (0.7 to 1.3 kPa). This water VPD can be considered a target for most production environments, occurring when the RH is 33% to 64% at 63F, 44% to 70% at 68F and 53% to 75% at 73F. The air is neither too dry nor too wet, so substrates and plants don't stay wet for long, nor do they dry very quickly (Figure 1). The driving force for the movement of water and nutrients from the roots through the shoots is moderate, but usually not excessive.



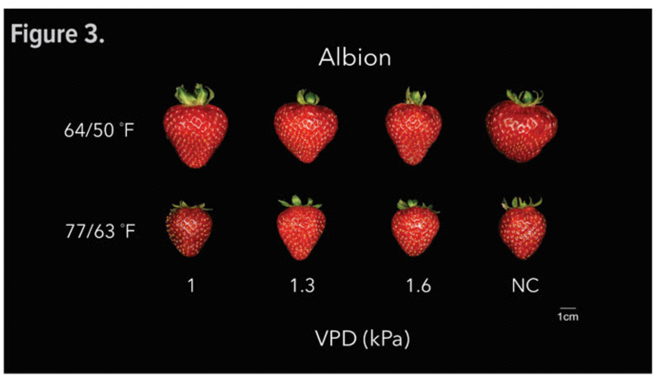


Figure 2 (top). Representative flowers and fruit of Albion, Cabrillo and Monterey grown at different day and night air temperatures for seven weeks.

Figure 3 (bottom). Fruit size of Albion grown at air day and night temperatures of 64/50F and 77/63F and under vapor pressure deficits (VPDs) of 1, 1.3, 1.6 or no VPD control (NC).

High VPD (>1.3 kPa). This can be considered a "dry air" environment, so water loss from plants and their substrates is relatively rapid (Figure 1). This occurs when the RH is below 24% at 63F, 36% at 68F and 46% at 73F. In some production situations, such as when plant canopies are large (e.g., high-wire vegetable production), plants may not be able to translocate water sufficiently, which can cause them to partly close their stomata, thereby limiting carbon dioxide uptake. As a result, the rate of photosynthesis decreases and the growth rate slows down.

VPD generally only becomes a crop production issue when at extremes. When the VPD is too low (less than 0.7 kPa, except during propagation), some pathogens can become more problematic and nutrient uptake may be insufficient to meet plant growth needs. When the VPD is very high (more than 1.5 kPa), the rate of water loss increases and, in response, photosynthesis in some crops can decrease.

Why strawberries need more attention

Consumer demand for strawberries continues to increase and growers are expanding production in greenhouses and vertical farms to provide year-round local fruit. Despite this growth, relatively little research has examined how VPD affects strawberry production compared to other greenhouse food crops such as lettuce, tomatoes and peppers.

To address this knowledge gap, we evaluated the effects of average daily temperature (ADT) and VPD on plant growth, yield and fruit quality characteristics. The objective was to determine how ADT and VPD influence yield and identify potential optimum growing conditions for each cultivar.

The study

Bareroot plants of the everbearing cultivars Albion, Cabrillo and Monterey were transplanted into greenhouse substrate troughs. Once plants were established, troughs were placed in one of five greenhouse compartments with day/night (D/N) temperature set points (12 h/12 h) of 59/45F, 64/50F, 70/55F, 75/61F or 81/66F (15/7C, 18/10C, 21/13C, 24/16C and 27/19C) and average daily temperatures ranging from approximately 52 to 73F (11 to 23C). Air temperature, relative humidity and light intensity were recorded and monitored to calculate the daily light integral (DLI) and vapor pressure deficit (VPD). Supplemental LED lighting maintained a 16-hour photoperiod when natural light was insufficient. Harvesting occurred twice weekly over a 12-week production period and yield efficiency was calculated as weekly fruit production.

Temperature strongly influenced yield

The clearest finding was that temperature significantly affected strawberry productivity.

Across all three cultivars, yield followed a similar pattern. Production declined at both the coolest (59/45F) and warmest (81/66F) D/N temperatures (ADTs of 52 and 73F), while plants at the intermediate temperatures consistently produced the highest berries and yields (Figures 2 and 3). The optimum ADT for yield efficiency generally ranged from 63.7 to 65.5F (17.6 to 18.6C).

Although each cultivar responded differently, the overall trend was consistent. Moderate temperatures supported the greatest productivity, while extremes reduced berry size and yield.

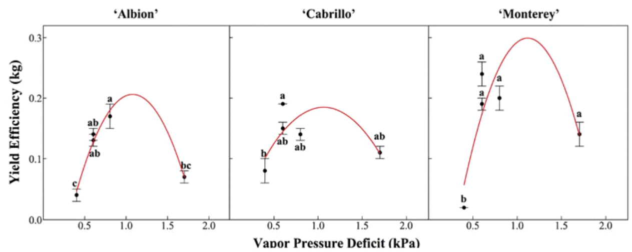
We concluded that across cultivars, plants were most productive at D/N temperatures of 64/50F to 75/61F (18/10C to 24/16C) or ADT of 57 to 68F (14 to 20C), as this range balanced vegetative growth, flower development and fruit production.

VPD still matters—but perhaps less than expected

We observed that yield responded to VPD, but the relationships were generally weaker and less consistent than those for temperature. Optimum VPD values ranged from approximately 1.1 to 1.3 kPa, depending on cultivar (Figure 3). At extremely low (<0.5 kPa) and high (>2.0 kPa) VPDs, yields were consistently lower (Figure 4). This suggests that strawberries benefit from a slightly higher, more moderate transpiration environment compared to other greenhouse food crops. However, the magnitude of the VPD effect was smaller than that of temperature.

This led to one of the study's most important conclusions: Temperature appears to be a stronger determinant of strawberry productivity than VPD under the conditions tested.

Figure 4.



Why extreme VPD conditions reduce yield

The physiological explanations behind these responses are consistent with previous crop research. At elevated VPDs, plants experience greater transpiration demand. If water loss exceeds the root system's ability to supply water, stomata begin to close. This limits carbon dioxide uptake, reduces photosynthesis and can ultimately slow fruit growth, development and yield. In addition to leaf physiology, strawberry flower development is particularly sensitive to VPD. High VPD can directly reduce pollen viability and flower size, and previous research has shown that smaller flower size often leads to lower fruit size and overall yield.

Figure 4. Yield efficiency in kg/trough/week of Albion, Cabrillo and Monterey under a range of vapor pressure deficits.

Similarly, low VPD environments can also reduce plant growth, development and yield. Under these conditions, transpiration rates decline, slowing nutrient transport and potentially affecting plant development. Excessively humid environments may also increase disease pressure, reducing leaf photosynthesis and marketable yield of berries.

Practical implications for growers

What does this mean for commercial greenhouse and indoor farm operators? First, temperature management should remain a primary focus as discussed in Article 1. While VPD monitoring provides valuable information, growers should ensure that temperature setpoints are optimized before investing heavily in advanced humidity-control strategies.

Second, maintaining moderate VPD levels is important. Growers should continue targeting moderate transpiration conditions while avoiding excessively humid (<0.7 kPa) or dry (>2.0 kPa) environments.

Third, cultivar-specific responses deserve less consideration for VPD control than temperature control. In this study, all three cultivars responded similarly to VPD (Figure 4).

Finally, growers should remember that VPD and temperature are inherently linked. As temperature increases, VPD typically increases as well. This relationship makes it difficult to entirely separate the effects of the two variables in commercial production environments.

The bottom line

VPD remains an important environmental metric because it influences transpiration, nutrient uptake, photosynthesis and plant water relations. For growers producing everbearing strawberries, the most productive environment appears to be one that combines moderate temperatures with moderate VPD conditions. However, this research also suggests that temperature may have a greater impact on strawberry yield than VPD alone.

As the industry continues to refine production practices, these findings provide a reminder that successful controlled environment strawberry production requires more than optimizing a single environmental metric. **IG**

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