St. Augustine Orchid Society
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Humidity and Vapor Pressure Deficit

by Sue Bottom, sbottom15@gmail.com

Relative humidity is a familiar term describing the amount of water vapor in the air compared to how much it can hold. Warmer air has a greater water holding capacity than colder air. Our orchids are comfortable in the same humidity range we enjoy, somewhere in the 40 to 70% range. Low humidity air dries out our skin and our plants leaves. Moderate humidity levels are desirable, but too high humidity can cause problems.

On a hot summer day, we sweat to cool our bodies through evaporation, although this works less well in the humid southeast than in the arid southwest, because water evaporates more quickly when humidity is lower. Plants also 'sweat' as water vapor evaporates from the leaf surface, cooling it. The evaporation rate slows as humidity levels increase because water cannot vaporize as quickly from the saturated leaf into a high humidity environment. High humidity also is conducive to the conditions that favor the growth of rots, molds and fungal infections.

Diurnal Changes. Typically, the humidity is highest around sunrise and lowest around midafternoon. As the air is warmed by the sun, it can hold more moisture. With each 20F increase in temperature, the amount of moisture the air can hold roughly doubles. Dew point, the temperature at which the air is saturated with water vapor, is a common meteorological term from which the relative humidity can be inferred. As the dew point temperature approaches the ambient temperature, the relative humidity approaches 100% because the air has become saturated with water. When there is a big difference between air and dew point temperatures, the humidity is low. Higher nighttime humidity levels are typical because the cooler night air can hold less moisture.

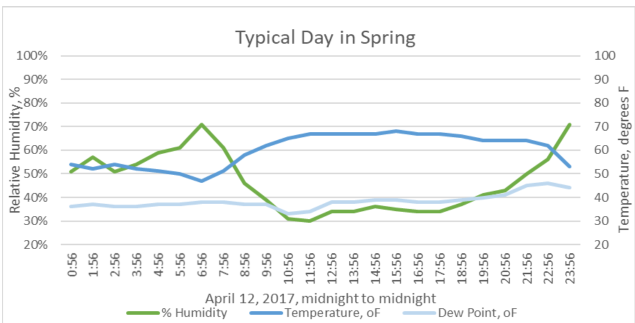
Seasonal Changes. There are seasonal humidity patterns that you can use to adjust your watering habits to match the evapotranspiration rate as well as understand when your plant is under disease pressure. You can get the hourly data from weather service sites like WeatherUnderground to create graphs for your area.

- On a typical spring day in St. Augustine, the temperatures and humidity levels are both moderate. The diurnal pattern for a random day in April shows the nighttime humidity is in the 50 to 70% range, dropping below 50% during the day. You notice your pots dry out much more rapidly at these low humidity levels, so you have to increase your watering frequency as a result. Nighttime humidity levels are usually not excessive unless we have a period of gray gloomy weather that is more reminiscent of winter.

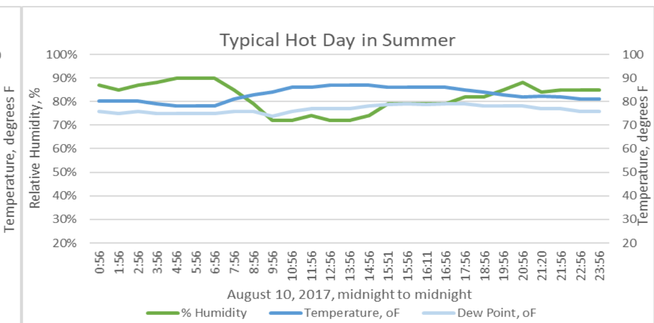
- In summer, both temperatures and relative humidity can be excessive, often not dropping below 80F at night when the humidity levels can climb above the 85% danger level. This environment encourages fungal pathogens because the water lost through the stomata is only slowly evaporated so it remains on the leaves longer. During periods of high disease pressure, applications of precautionary fungicide sprays and drenches may be warranted. Pots do not dry rapidly, so you may water less frequently than you do in the spring.

- When the temperature and humidity mediate in the fall, you notice a growth spurt in your orchids. The daytime humidity levels are low so pots dry out more rapidly and you find yourself watering more frequently than you did during the summer. Nighttime humidity levels are usually not too excessive, until the tropical storm season. The leaf wetness and lack of drying that accompanies these extended periods of gray, rainy weather are invitations to disease. If your plants cannot be sheltered from the weather, before and after fungicide and bacterial sprays are warranted.

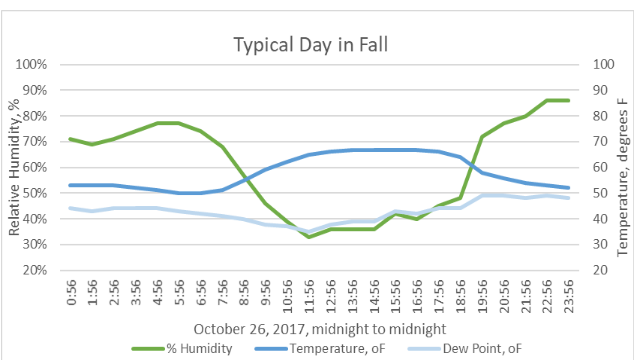
★ Our winters typical include 10 to 14 days of cold to freezing weather when both the temperatures and humidity are very low. More enjoyable are the periods when it warms up during the day, The cooler nighttime temperatures and high humidity encourage condensation on plant leaves and that is a recipe for both mesophyll cell collapse from cold water damage as well as rots and bacterial problems. The dreaded flower blighting from Botrytis is common during the high humidity evening hours, requiring either more air movement to dry leaves and flowers or higher temperatures to drop humidity.



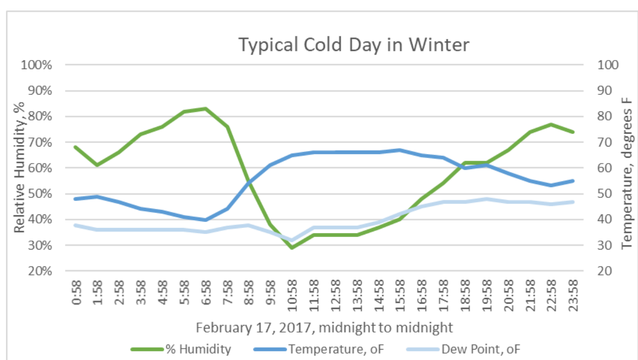
1. Typical Spring Day in St. Augustine



2. Typical Summer Day in St. Augustine



3. Typical Fall Day in St. Augustine



4. Typical Winter Day in St. Augustine

Vapor Pressure Deficit. Though humidity is a useful and familiar measure, there is a more precise way to express the driving force of water loss from the leaf, vapor pressure deficit. Vapor pressure deficit (VPD) is a measure of the evaporative forces at the leaf surface, given in pressure units like millibars (mb) or kilopascals (kPa). It is defined as the difference between the pressure exerted by water vapor in saturated air and water vapor actually present in the air. At a VPD of zero, the air is at its dew point so there is no moisture gradient between the plant leaves and the air that are both saturated with moisture. A low VPD indicates the air is near saturation so the transpiration rate is negligible. A high VPD means the air is drier, and the moisture gradient between the leaf and the atmosphere encourages a higher transpiration rate.

We could find no recommended VPD levels for orchids, but some guidance is offered in an article by Wollaeger and Runkle (2015):

> *Growers should aim to have fairly low VPD, for example 0.3 kPa, when rooting cuttings in greenhouses. This will reduce the drying of young plants, thereby reducing the frequency of misting and watering required to keep plants hydrated. However, Michigan State University Extension recommends maintaining a greater VPD (greater than 0.5 kPa) in greenhouses while finishing plants, especially when there is a dense plant canopy. Plants will be able to transpire, cool themselves and be less stressed while the environment is less conducive to disease.*
>
> *Greenhouse vegetable growers harvesting fruits should be aware that one study, "Vapor Pressure Deficit (VPD) Effects on the Physiology and Yield of Greenhouse Tomato," reported that a VPD of 0.8 kPa during the day and night increased photosynthetic rates and tomato fruit yields compared to plants grown with a VPD of 0.5 kPa. Too dry of an environment can also cause problems. For example, another study, "High Vapor Pressure Deficit Influences Growth, Transpiration and Quality of Tomato Fruits," showed that a very high VPD of 2.2 kPa could cause plant stress and fruit cracking in tomato.*

Plant metabolic processes require the plant to absorb carbon dioxide through the stomata in the leaves to produce food, and water to be absorbed largely through the roots and drawn into the plant in the transpiration stream, exiting the stomata as water vapor. A moderate to high transpiration rate encourages the uptake of mineral nutrients through the roots.

- Where the vapor pressure deficit is in the optimum range, the plant has a moderate transpiration rate so water and mineral nutrients can be absorbed from the roots, water loss through the open stomata is not excessive and carbon dioxide can be absorbed through the open stomata to produce food. We guesstimate the optimum range to be around 0.5 to 1.2 kPa for many thin leaved orchids using the normal photosynthetic pathway. Thick leaved orchids with CAM metabolism have adapted to endure higher VPD deficits, opening their stomata only at night when humidity is higher.
- In an overly dry atmosphere, where the vapor pressure deficit is high (perhaps over 1.2 kPa), moisture is evaporated rapidly through the open stomata, sometimes so much so that the plant will shut its stomata in an attempt to limit water loss. With closed stomata, leaves cannot cool themselves and carbon dioxide cannot be absorbed from the atmosphere. Spider mites also thrive in a dry environment.
- In an overly wet atmosphere, where the vapor pressure deficit is low (perhaps below 0.5 kPa), the stomata can remain open for carbon dioxide uptake. Moisture is slowly evaporated from the foliage though the transpiration rate is slowed. A weak transpiration flow can result in nutrient deficiencies, particularly of calcium. Edema, the physiological

response to a plant's inability to shed water, can cause leaf blistering. Disease pressure is high because of the potential for excessive leaf wetness.

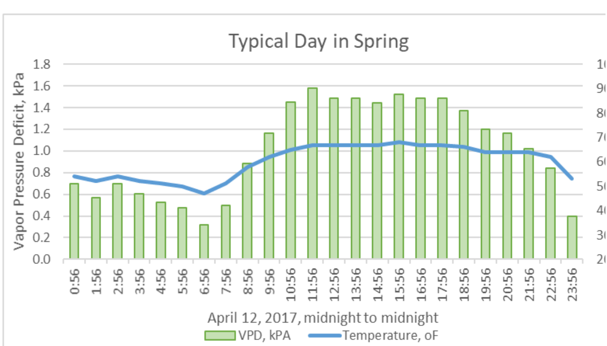
Plants respond to the VPD by increasing or decreasing the stomatal opening, and this in turn affects the ability of the plant to absorb carbon dioxide, water and mineral nutrition as well as cool itself during hot weather. There are orchids that normally have their stomata open during daylight (C3 plants, often thin-leafed orchids like oncidiums). These plants absorb carbon dioxide and photosynthesize during daylight hours, and can cool their leaves through evaporation. Others orchids have adapted to an epiphytic lifestyle by opening their stomata in late afternoon and through the night (CAM plants, often thick-leafed orchids like cattleyas) when humidity is higher as a water conservation measure. These orchids absorb carbon dioxide at night when the humidity is higher and store it until the daylight hours when photosynthesis occurs.

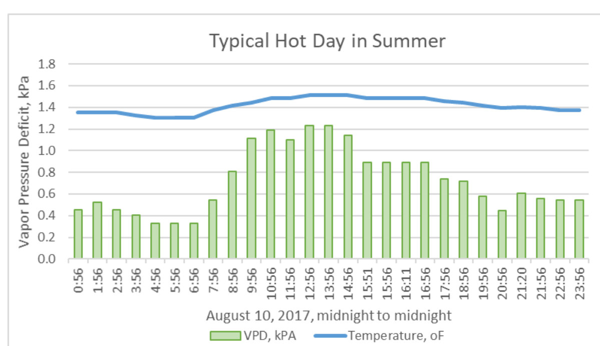
- The VPD in spring tends to be moderate to high during the daylight hours with most values over 1.2 kPa. C3 plants will lose water rapidly through evapotranspiration so watering frequency should be increased. Nighttime VPD values are moderate so CAM plants should grow well with warming temperatures, increased sunlight and ideal VPD in spring.

- The summertime VPD tends to stay in the moderate range during daylight hours but drops to low levels at night. C3 plants can cool themselves during the heat of the day while additional shading or under bench wetting may be necessary for CAM plants that cannot cool themselves through evapotranspiration by day. Nighttime VPD levels are low so nutrient uptake particularly of calcium is low and disease pressure is high.

- The fall diurnal patterns are similar to spring, with the difference being that temperatures are decreasing as are the hours of daylight. You will water a little more during the fall growth spurt particularly for those plants that enjoy the cool weather; others are preparing themselves for the winter rest.

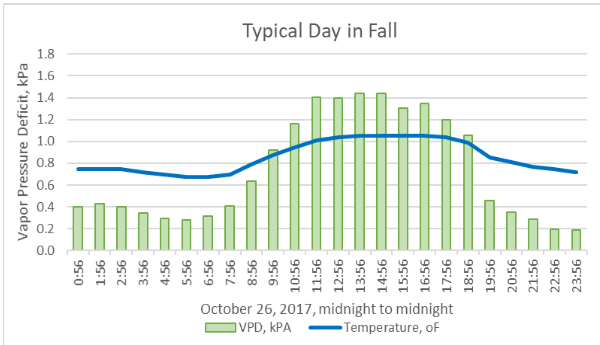
- We enjoy moderate temperatures on many winter days, and the vapor pressure deficit is often in the low range day and night. This means our C3 and CAM orchids can absorb plenty of carbon dioxide without excessive water loss but transpiration rates are low reducing the need for frequent watering and mineral nutrition.

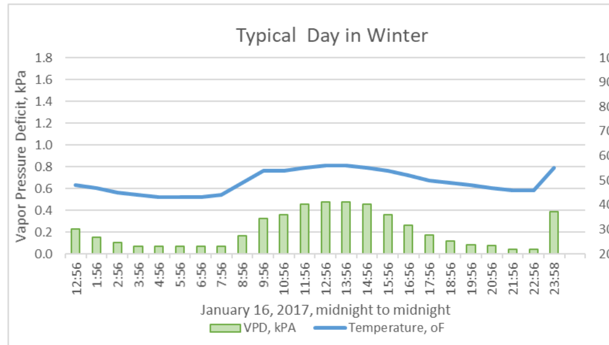




5. Typical Spring Day in St. Augustine

6. Typical Summer Day in St. Augustine





7. Typical Fall Day in St. Augustine

8. Typical Winter Day in St. Augustine

Indoor growers and growers in the arid southwest have to take additional steps to prevent plant stress from excessive vapor pressure deficits. Our orchids grow well outdoors during much of the year, except during the cold winter periods and wet tropical storms in late summer and fall. Understanding the vapor pressure deficit that occurs during each season will help guide you in your watering and fertilizing frequency. It also explains why additional shading may be required in summer for cooling, and when disease pressure may be high.

Acknowledgements. I always appreciate it when people write to me, correct my mistakes, ask questions and open my mind to new thoughts. Thank you Anna Meigs for introducing me to the topic of vapor pressure deficit and its implications for orchid growing. What a wonderful world, when we can share ideas and thoughts across the miles, and gather new friends in the process!

Citations and Additional Reading:

Leonardi C., Guichard S., Bertin N., High vapour pressure deficit influences growth, transpiration and quality of tomato fruits, *Scientia Horticulturae* 84(3-4):285-296, 2000.

Monteith J.L. Unsworth M.H. 1990. Principles of environmental physics. Edward Arnold, Sevenoaks.

Murray F.W. 1967. On the computation of saturation vapor pressure. J. Appl. Meteorol. 6. 203-204.

Prenger J. J. and P. P. Ling. *Greenhouse Condensation Control: Understanding and Using Vapor Pressure Deficit (VPD)*. Ohio State University.

Wollaeger H. and E. Runkle. 2015. *Why should greenhouse growers pay attention to vapor-pressure deficit and not relative humidity?* Michigan State University Extension and MSU Department of Horticulture.

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Zhang D, Du Q, Zhang Z, Jiao X, Song X, Li J. Vapour pressure deficit control in relation to water transport and water productivity in greenhouse tomato production during summer. *Scientific Reports*. 2017;7:43461. doi:10.1038/srep43461.

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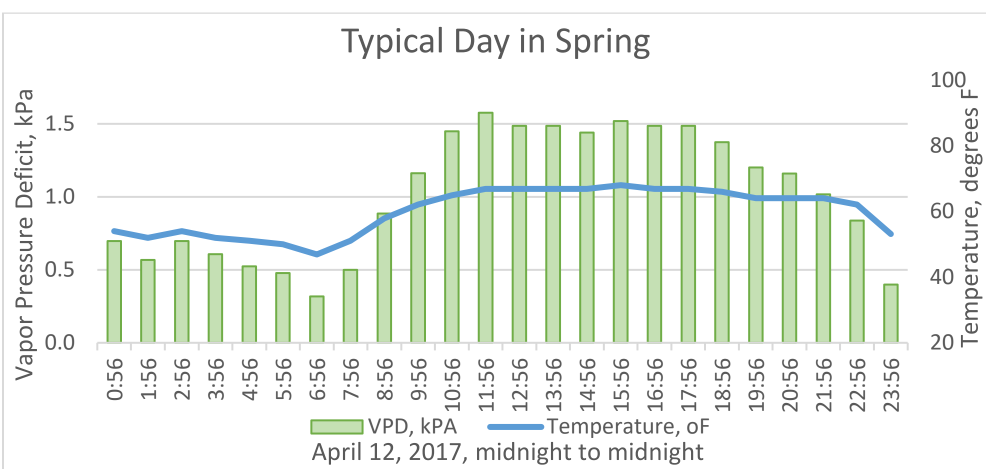
Sidebar – Create VPD Charts for Your Geographical Area

1. Find a source of hourly temperature and humidity readings that approximates your conditions. Wunderground.com is a great source of information. Once you have decided on a weather station, click on the historical button to find data compilations by day, week or month. Scroll through the monthly data and find a day that seems to represent the typical weather pattern for the season in question. Switch over to the daily data summary for that day to get the hourly readings.
2. Copy all the hourly data including the column headers into an excel spreadsheet and title that worksheet as the day in question.
3. Create a second work sheet labeled with the season and copy the columns with time, temperature and humidity into the worksheet. You will have to format the time as you want it to appear on the x-axis, remove the symbols for temperature and percent from these columns, make sure the temperature is formatted as a number and the humidity is formatted as a percentage. If the temperature is given in degrees Fahrenheit, create another column to convert all the values to degrees Centigrade (^{o}C=(^{o}F/1.8)-32).
4. Your final column will be the Vapor Pressure Deficit, calculated from the formulas for Saturation Vapor Pressure SVP (kPa) = $0.6107*10^{7.5T/(237.3+T)}$ where T is in ^{o}C and VPD = (1 - RH)*SVP where the RH is in percent. These equations can be combined and represented in excel as VPD = (1-RH)*(0.6107*(POWER(10,(7.5*T)/(237.3+T)))).

5. The first few rows look like this:

Time	Temp, ^{o}F	Humidity	VPD, kPA	Temp, ^{o}C
0:56	54	51%	0.70	12.2
1:56	52	57%	0.57	11.1
2:56	54	51%	0.70	12.2
3:56	52	54%	0.61	11.1
4:56	51	59%	0.52	10.6

6. Then you can create a chart that could be formatted like this:



Equation citation: http://cronklab.wikidot.com/calculation-of-vapour-pressure-deficit