What is the ideal nutrient solution temperature in hydroponics?

One of the simplest variables that can make a substantial difference in crop yields in hydroponics is the temperature of the nutrient solution. Nutrient absorption by plants is mainly controlled by chemical processes within their roots and the efficacy of these processes is determined in an important part by the temperature the roots are subjected to. Since plants don’t have a mechanism for active temperature regulation they just react to changes in temperature in order to best adapt to the environment that surrounds them. Today I will be talking about the optimum solution temperature in hydroponics, what influences this value and what factors we must consider when deciding what temperature to use in our hydroponic system.

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Table 2. Fresh weight, dry weight, water content and SLA of red leaf lettuce grown at four different root zone temperatures.

Root-zone temp.	Top fresh weight (g)	Root fresh weight (g)	Top dry weight (mg)	Root dry weight (mg)	Top water content (%)	Root water content (%)	SLA
10˚C	3.12 ± 0.20 b	0.61 ± 0.04 b	211 ± 9 a	36 ± 2 a	93.2 ± 0.1 b	93.2 ± 0.2 b	0.51 ± 0.02 b
20˚C	4.60 ± 0.28 a	0.98 ± 0.14 a	253 ± 12 a	44 ± 6 a	94.5 ± 0.1 a	95.5 ± 0.1 a	0.57 ± 0.02 a
25˚C	4.51 ± 0.42 a	0.82 ± 0.07 ab	251 ± 20 a	38 ± 3 a	94.4 ± 0.1 a	95.3 ± 0.1 a	0.54 ± 0.01 ab
30˚C	4.11 ± 0.35 ab	0.75 ± 0.11 ab	233 ± 19 a	35 ± 6 a	94.3 ± 0.1 a	95.4 ± 0.1 a	0.56 ± 0.02 ab

Values are mean ± SE (n = 6). Different letters in the same column indicate significant differences by Tukey’s multiple comparison test ($p < 0.05$).

Figure 1. Effect of root-zone temperature on the morphology of red leaf lettuce.

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Solution temperature affects several important variables. Oxygen solubility changes as a function of temperature – decreasing as temperature increases – so as you increase the temperature the availability of oxygen to plant roots starts decreasing. As you increase temperature however the speed of the chemical reactions in plant roots increases, so there is an increase in respiration rates as temperature increases. The ideal temperature is therefore always a compromise between this decrease in oxygen availability and the increase in metabolic rate that is given by higher temperatures. For almost all commercially grown plant species optimum solution temperatures will be in the 15-30°C (59-86F) range due to this reason.

However there is no rule of thumb for optimum solution temperature selection in hydroponics. It should be clear that since different plants evolved across different conditions some of them perform better at lower temperatures and some others do better at higher temperatures. We know for example that the optimum nutrient solution temperature for potatoes is in the 20-25°C range (see here) while the optimum temperature for plants like cucumbers is higher, at 28°C (see here). For some plants like onions the best solution temperature can actually be a bit higher, even in the 26-30°C range (see here). Others like lettuce and baby leaf crops actually prefer much lower temperatures, with optimum results near 20°C (see here and here).

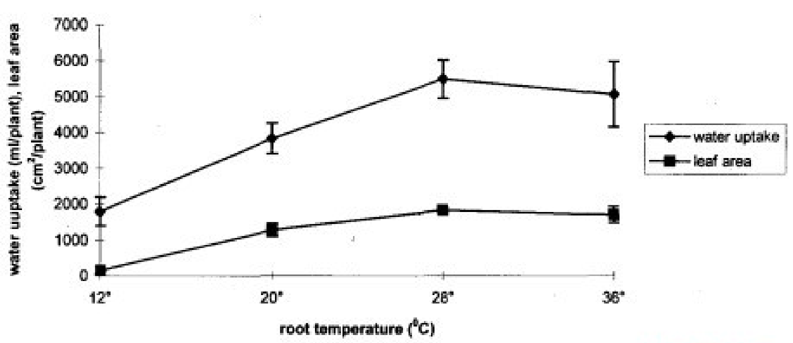

Figure 1. Water uptake and leaf area as affected by root temperature. Cucumber

It is then clear that picking a random number between 15-30°C is not enough, a careful study of the plant specie being grown has to be carried out in order to select an adequate temperature. It is also important to note that higher temperature choices do not come without problems. We know for example that pythium and other infections are associated with increases in temperature since pathogen metabolism is also enhanced under warmer conditions (see here and here). This shows how even though the optimum temperature for tropical flowering plants is usually in the 25-30°C range, it is usually not common to see optimum results at these temperatures due to the potentially higher prevalence of diseases. This is most probably why growers usually go with a lower temperature in the 20-25°C to avoid risking diseases at a higher temperature.

If you want to try higher temperatures it is therefore better to go with sterile type hydroponic systems where microbes don't play an important role and to implement measures – such as silicate additions to the nutrient solution, UV filtration and constant oxygenation – to ensure that disease prevalence is as low as possible. Also avoid adding any source of organic carbon (like sugars) as these can play an important role in feeding incoming pathogens. Big gains can be obtained with a better solution temperature control, provided that diseases are controlled and a temperature adequate for the plant being grown is selected.

Vapor pressure deficit (VPD) in hydroponics

If you have read books or articles about greenhouse environmental control you have probably heard about Vapor Pressure Deficit, also known as VPD. This is an important variable to measure as it helps us understand the conditions our plants are facing, gauge their water use and even predict whether we will be getting better or worse yields. Today I am going to talk about vapor pressure deficit in hydroponics, what this variable means, what it takes to control it and why it is so important to understand and even change this value to obtain better results.

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Table 3. References VPD (kPa) for greenhouse production, recommended by Argus Ltd, (2009)

T(°C)	rH (%)													
	35	40	45	50	55	60	65	70	75	80	85	90	95	100
15	1.11	1.02	0.94	0.85	0.77	0.68	0.60	0.51	0.43	0.34	0.26	0.17	0.09	0
16	1.18	1.09	1.00	0.91	0.82	0.73	0.64	0.55	0.45	0.36	0.27	0.18	0.09	0
17	1.26	1.16	1.06	0.97	0.87	0.77	0.68	0.58	0.48	0.39	0.29	0.19	0.10	0
18	1.34	1.24	1.13	1.03	0.93	0.83	0.72	0.62	0.52	0.41	0.31	0.21	0.10	0
19	1.43	1.32	1.21	1.10	0.99	0.88	0.77	0.66	0.55	0.44	0.33	0.22	0.11	0
20	1.52	1.40	1.29	1.17	1.05	0.93	0.82	0.70	0.58	0.47	0.35	0.23	0.12	0
21	1.62	1.49	1.37	1.24	1.12	0.99	0.87	0.75	0.62	0.50	0.37	0.25	0.12	0
22	1.72	1.59	1.45	1.32	1.19	1.06	0.92	0.79	0.66	0.53	0.40	0.26	0.13	0
23	1.82	1.68	1.54	1.40	1.26	1.12	0.98	0.84	0.70	0.56	0.42	0.28	0.14	0
24	1.94	1.79	1.64	1.49	1.34	1.19	1.04	0.89	0.75	0.60	0.45	0.30	0.15	0
25	2.06	1.90	1.74	1.58	1.42	1.27	1.11	0.95	0.79	0.63	0.47	0.32	0.16	0
26	2.18	2.02	1.85	1.68	1.51	1.34	1.18	1.01	0.84	0.67	0.50	0.34	0.17	0
27	2.32	2.14	1.96	1.78	1.60	1.43	1.25	1.07	0.89	0.71	0.53	0.36	0.18	0
28	2.46	2.27	2.08	1.89	1.70	1.51	1.32	1.13	0.94	0.76	0.57	0.38	0.19	0
29	2.60	2.40	2.20	2.00	1.80	1.60	1.40	1.20	1.00	0.80	0.60	0.40	0.20	0
30	2.76	2.54	2.33	2.12	1.91	1.70	1.48	1.27	1.06	0.85	0.64	0.42	0.21	0
31	2.92	2.69	2.47	2.24	2.02	1.80	1.57	1.35	1.12	0.90	0.67	0.45	0.22	0
32	3.09	2.85	2.61	2.38	2.14	1.90	1.66	1.43	1.19	0.95	0.71	0.48	0.24	0
33	3.27	3.02	2.76	2.51	2.26	2.01	1.76	1.51	1.26	1.01	0.75	0.50	0.25	0
34	3.46	3.19	2.92	2.66	2.39	2.13	1.86	1.59	1.33	1.06	0.80	0.53	0.27	0
35	3.65	3.37	3.09	2.81	2.53	2.25	1.97	1.69	1.40	1.12	0.84	0.56	0.28	0

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Vapor pressure deficit – measured in kPa – basically measures how much water vapor pressure we would need to put into a room with a certain humidity and temperature to get it to the point where relative humidity would be 100%. The larger the VPD the more water you need to put into the air to get it to saturate while the lower the VPD the closer the air is to full saturation. Since air holds more water with increasing temperature this means that at a fixed relative humidity the VPD is directly proportional to the room’s temperature. This simply means that the hotter the room, the higher the VPD and the colder the room, the smaller the VPD if humidity remains constant.

The problem with a very low VPD – room close to 100% humidity – is two fold. First, it’s difficult for any organism to evaporate water and second, it’s easy for water to condense on any surface it temperature drops just a bit. For humans this basically means having to wear a t-shirt soaked with your own sweat but for plants this means both an inability to cool their surfaces and an inability to transport nutrients to their leaves. A low VPD generates a lot of stress because it makes plants unable to properly transport water.

A high VPD is equally problematic as it means that the plants need to transpire a lot. If air can hold a lot of additional water vapor this means that plants will lose more water through their stomata and this permanent loss puts pressure on the roots to transport more and more water. If root mass is not large enough or water availability is not high enough then plants will face important problems and will simply tend to wilt as the air takes away more water than what the plant can effectively transport through its tissues. You can actually often create models using VPD to predict a crop’s water usage (see image below).

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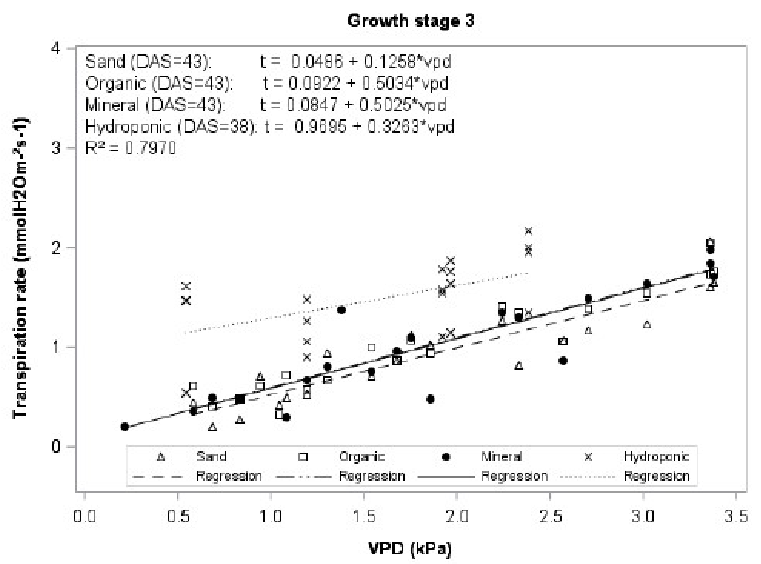

Figure 7: Transpiration rate in Panicum (*Panicum maximum* cv. *tanzania*) under VPD with different substrates in growth stage three.

The first graph in this post (which I took from this study on tomatoes) shows the optimum VPD – in green – as a function of humidity and temperature for greenhouse production of tomatoes. In general a range between 0.5 and 1.1 seems to work best but the window under which these conditions are possible becomes narrower as temperature increases. Ideally we would want to be somewhere around 20-25°C where we should sustain humidity values between 65-70%. This would give us a VPD value between 0.7-0.8 which is around what is commonly held to be most beneficial for greenhouse crops under normal conditions.

However optimal VPD can also change depending on lighting conditions and other sources of supplementation. For example the optimal VPD during the day is usually higher than the optimal VPD during the night. In general it's better to have a drop in VPD during the night relative to the VPD that is maintained during the day. Declines in canopy carbon dioxide exchange rates can be correlated with increases in the VPD during this time (see here for a study about this on soy bean). If you're supplementing carbon dioxide – which puts further transpiration stress on the plants – the optimal VPD is also likely to be lower than if you didn't use any supplementation at all (you can see a practical application of this here).

Changing the VPD can be a challenge but under closed environments it is much easier to do. You can reduce the humidity using a dehumidifier to increase your VPD and you can use a humidifier to increase your VPD. Ideally you will want to use an AC unit to keep your temperature at exactly the value you want it to be and you can then use a humidifier/dehumidifier to control the exact point where you want your VPD to be by controlling the value of your relative humidity at the fixed temperature provided by the AC unit.