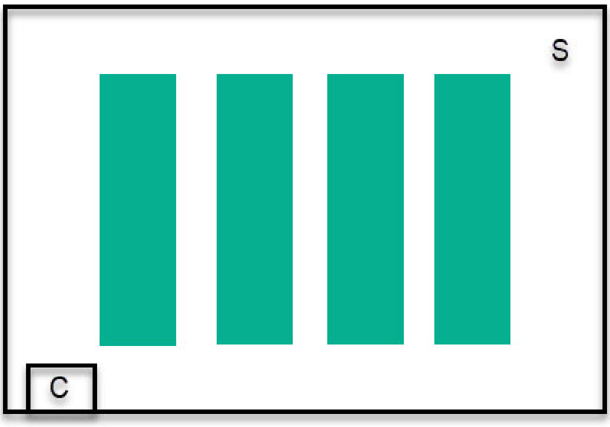
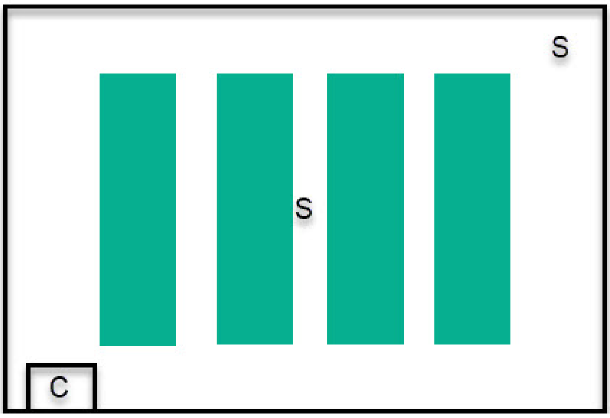
Properly positioning temperature and humidity sensors in a hydroponic growing environment

Temperature and humidity are two key variables you need to measure. They are important because they determine how your plants will transport water, and transpiration controls a lot of processes, with nutrient transport being one of the most important ones. However, the value of these variables in a growing environment – being that a greenhouse or a grow room – can change substantially depending on where they are measured. It is therefore critical to know where to place sensors and how to interpret their readings based on their location. In this post, we are going to discuss where it is best to measure these variables and what consequences it could have if these values are not measured properly.

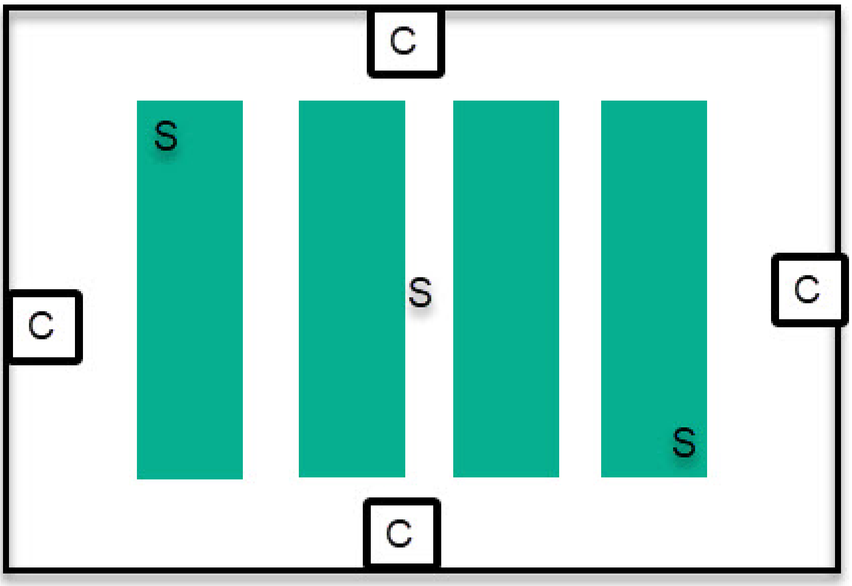




Sensor placement relative to a control source (AC, humidifier/dehumidifier) for one or two sensors. Note that this setup assumes good circulation throughout the room, including middle of canopy.

Let's start with the worst possible case, you only have one set of sensors and you need to control your environment with it. *In this case, place your temperature and humidity sensors at canopy height, as far away as possible from both the AC ducts and the humidifier/dehumidifier, make sure the sensors are hanging in the air and not stuck to a wall or tubing*. Then, make sure you use a hot wire anemometer to verify that your air movement speed is at least 0.3m/s across the entire room. This setup ensures that the worst controlled part of the room is at the correct value and it also attempts to minimize the gradient created from the control sources to the sensor using a good amount of air circulation. It is not perfect though and significantly different "climate zones" will be created close to and far away from the climate control devices.

The above setup can be used effectively in small growing environments, but can be problematic as both the number of plants and the size of the growing environment increases. At this point, using a single set of sensors is not an option if adequate climate control is desired. In these cases, multiple sensors need to be placed to ensure that climate control is being done properly. When using multiple sensors, place the second sensor at the place with the lowest air circulation inside the room, at canopy height, which is usually in the middle of the room, then place subsequence sensors as far away from either this or the first sensor in sequence. When doing climate control, the system needs to ensure all of the sensors remain within a “safety band”, making sure no sensor becomes too cold/hot, humid/dry, during control cycles.



Sensor placement for multiple control sources. Sensors are placed in order trying to always be as far away from sensors as possible but within the plant canopy.

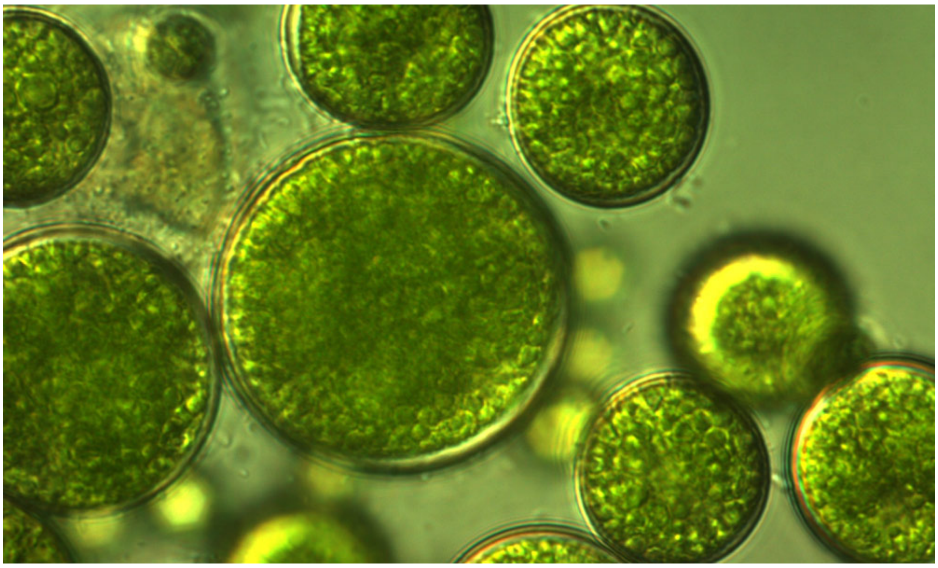
When you implement a sensor system like this, you will realize pretty quickly that climate becomes very hard to control in a larger room when there is only one source of control (one AC, one humidifier, and one dehumidifier) because gradients become too big for effective control, so it takes too long for the AC to be able to properly control the room while ensuring all sensors remain within proper boundaries. In this case, it becomes necessary to add multiple sources of control, so that the extent of gradients within the room can be minimized. This means adding multiple ducts for the output of an AC, multiple humidifier/dehumidifiers, etc.

In these cases, sources of control are placed outside of the plant canopy to avoid plants being exposed to the flows from these control sources (which would expose them to very cold/hot/dry/humid air). Then the sensors need to be placed within the plant canopy, starting from as far away as possible from all sources of control – usually the middle of the canopy – and then to the corners of the growing environment.

Note that the control algorithm needs to ensure all of these sensors are within the proper control band and not attempt to control the average reading of these sensors. If you try to use the average of sensors to control a room, you might be left with a room where two extremes are present and the control system believes everything is ok while these extremes are maintained. The median is a better way to control a room, but it only becomes useful when 5 or more sensors are used. If only 2 or 3 sensors are used, ensuring all of these sensors are within adequate bands is fundamental to ensure that the room will have a lower chance of having humidity/temperature microclimates that will be detrimental to plant growth.

How to control algae in a hydroponic crop

Microscopic algae can be a very annoying problem in a hydroponic crop. As photosynthetic organisms they can cover all exposed surfaces that get wet with hydroponic nutrient solution and can cause a wide variety of different issues for the grower. They can also be hard to control, reason why some growers simply choose to ignore them and learn to "live with them" as a fundamental part of their hydroponic setup. In today's article we'll talk about some of the reasons why microscopic algae are a problem that has to be dealt with, what the different options to solve the problem are and which of these options can be the most effective.



Typical microscopic algae found in hydroponic nutrient solutions

Besides the unpleasant look of algae covered growing media, these microscopic organisms can cause some important problems in your hydroponic crop. They can deprive hydroponic solutions from some nutrients, generate substances that can hinder plant growth, serve as food for some insects (like fungus gnats) and also serve as food for other microscopic pathogens. For more information about algae and their effects you can read this paper that studied some of the effects of algae in hydroponic crops or this white paper that explains some of the main issues associated with algae in hydroponics. This paper also studies nutritional and pH effects in more depth.

The first barrier of defense against algae is to avoid them, cover surfaces that are exposed to light and nutrient solution with opaque covers and ensure that all surfaces are properly sanitized before hydroponic crops are started. Granted this is a limited solution in scope – as places like the top of media are not easy to cover – but it can provide some protection compared to a crop where no attention is paid to surfaces at all.

To deal with surfaces that have algae in them is an entirely different matter. *Algae are not easy to get rid of*. This paper goes through multiple potential treatments to get rid of algae, including the use of fungicides, insecticides and algicides and finds that these substances are either not effective, only preventive in nature or actually phytotoxic at the concentration at which they are effective. Hydrogen peroxide is suggested as a potential solution to deal with algae, but hydrogen peroxide also causes significant stress in plant roots and its application is bound to have only limited success, with the algae coming back to recolonize – often more strongly – once the applications are finished. This paper evaluates hydrogen peroxide use even further and also shows some of the potential problems that can happen when using it to control algae and insects.

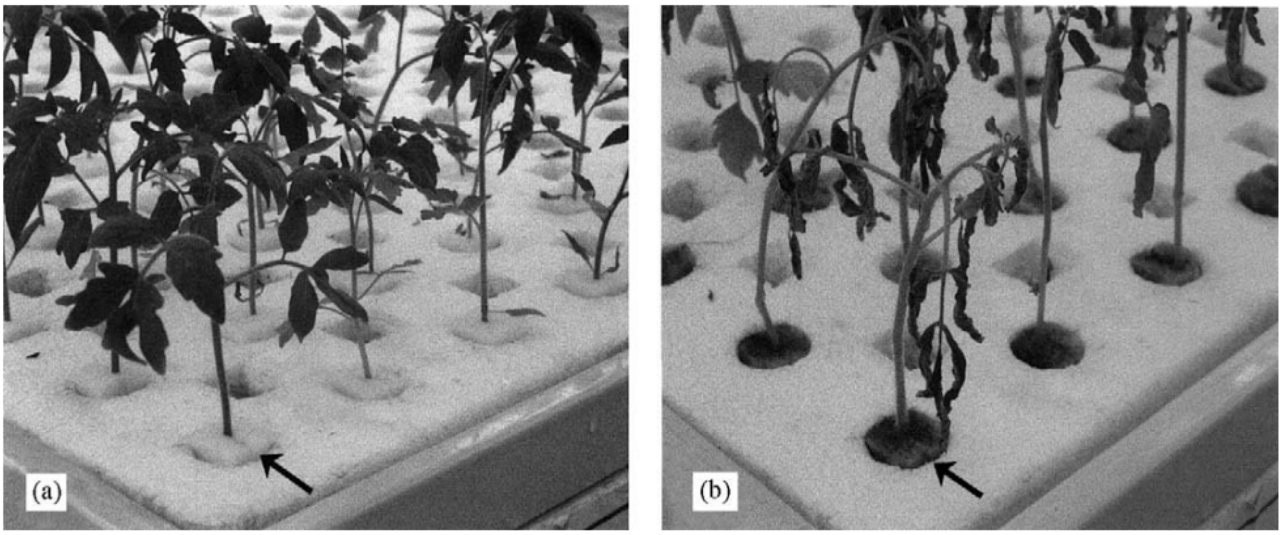


Image from this article showing plants treated with IBA (a) and plants not treated with it. You can notice the complete absence of algae in the growing media

Thankfully all hope is not lost. Around 20 years ago, experimentation started on the use of some indole derivatives – the same used to stimulate rooting in rooting gel formulations – to control algae populations. [This article](#) shows that an application of 3-(3-indolyl)butanoic acid (also known as IBA or Indole-3-butyric acid) at 10 ppm can very effectively control algae populations. The image above shows how the IBA treatment was very effective at reducing all algae growth in the media, even when nutrient solution was directly wetting the media with direct access to light. This is great news since IBA is non-phytotoxic and can therefore be used without having to cause any damage to the plants (unlike peroxide does). There is also additional evidence from independent researchers in Japan showing the effectiveness of IBA for the same purpose (see this article). Additionally there might even be some positive effects of IBA applications in crop yields, as it is shown in this paper where experiments with IBA applications were done on bell pepper. This is not terribly surprising given that the effects of IBA to stimulate root growth are very well known.

Note that although the above articles use IBA as a consistent application during the entire crop, there is little peer reviewed use of IBA applications in plants during their entire crop cycle. To avoid any potentially unknown effects – such as substantial changes in essential oil or product characteristics – it is important to test the effect in the particular plant you are growing and initially apply it only as needed to control any algae growth that might appear. Some areas might also forbid the application of substances like IBA – which is a recognized Plant Growth Regulator (PGR) – so make sure you can also use this in your crop before you even consider it for this application. This 2009 proposal to allow IBA usage in organic food production and handling goes a lot deeper into IBA, its use in plants and its potential effects.

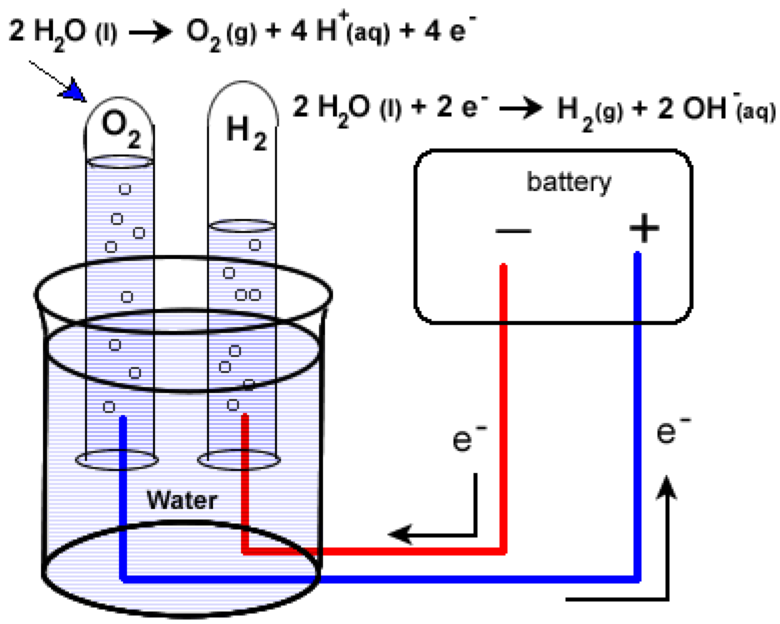
Controlling pH in hydroponics using only electricity

The ability of plants to assimilate nutrients changes as a function of pH. This makes maintaining the pH of nutrient solutions within an acceptable range – most commonly 5.8 to 6.2 – one of the most important tasks in a hydroponic crop. This is commonly done with the addition of strong acids or bases to decrease or increase the pH when it drifts away from the intended value. This requires either manual monitoring with careful addition of these substances or automated processes using pumps to ensure the pH always remains at the correct value. However both of these methods lack fine control, require a lot of maintenance and monitoring and can lead to costly mistakes. Today I want to discuss an alternative method that relies on a completely different idea to control pH, the idea that we can oxidize or reduce water using electricity to achieve changes in pH. **Yes, you can change pH using literally only electricity**.

A modern anion exchange membrane. Fundamental to the idea of an electricty-only pH control system

Let's start by discussing pH and talking about how it is changes. The pH of a solution is calculated as -Log(|H^+|) where |H^+| is the molar concentration of H^+ ions in solution. In water, the dissociation constant 1×10^{-14} (at 25C), always needs to be respected, so we always know that the product of |H^+| and |OH^-| needs to give us this number. When you add acids you increase |H^+| conversely |OH^-| decreases and the pH goes down, when you add bases |OH-| increases, |H+| decreases and the pH goes up. *In simpler terms everything you need to decrease pH is a source of* H^+ *and everything you need to increase pH is a source of* OH^-.

This is where electrochemisty gives us the simplest solution we could hope for. Water can be oxidized or reduced. When you run a current through water – above the minimum required voltage – water splits into hydrogen and oxygen molecules. In the image below you can see how the water oxidation reaction generates H+ ions while the reaction on the right generates OH- ions. When you do this in a single cell – as shown below – the H+ ions generated at the anode react with the OH- ions generated at the cathode and the pH of the solution remains neutral while oxygen is produced at the anode and hydrogen is produced at the cathode.



The image above shows the half reactions involved in the oxidation (left) and reduction (right) of water.

However, we can take advantage of ion exchange membranes to separate these two processes, allowing us to control where each reaction happens and where the acid or base is generated (preventing them from just mixing and neutralizing). As a matter of fact, all we need is to have an electrode in our nutrient solution and another electrode in an auxiliary cell, separated from our nutrient solution by an ion exchange membrane. This concept is actually not new and was already proposed in a 1998 paper to control pH in hydroponic systems. Although it was never tried in a production system, all the concepts were validated and were shown to perform adequately in test solutions.

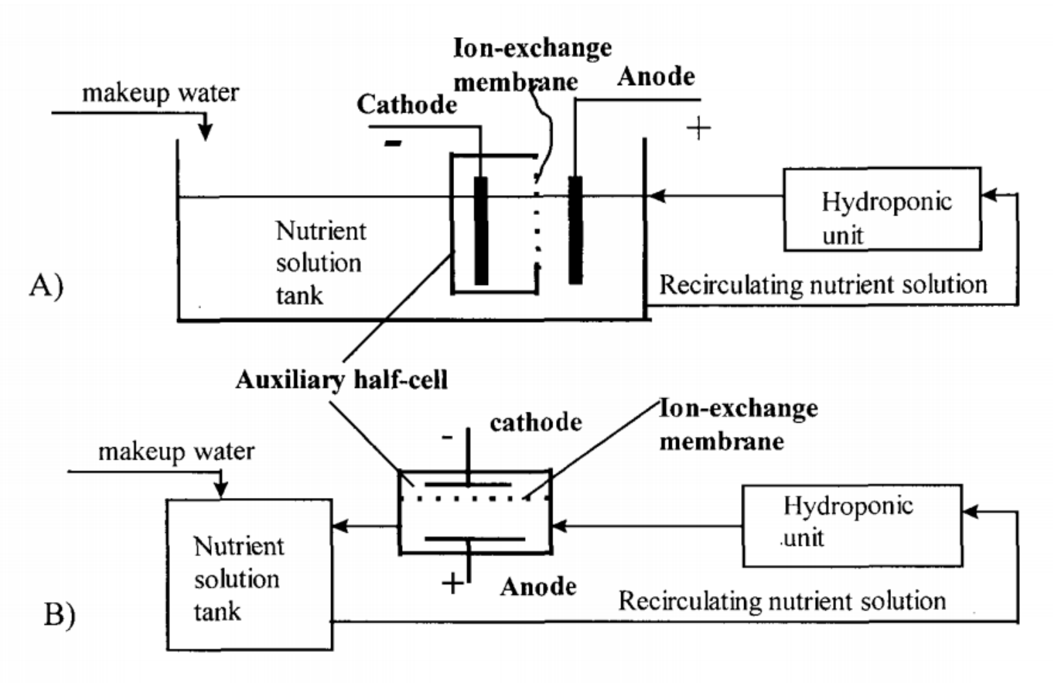


Image taken from this paper, which discussed the topic of electrochemical pH control in hydroponic systems at length.

One of the big challenges of this setup is that the cathode side involves hydrogen gas evolution – which could be dangerous – but can be completely avoided by replacing the cathode's half reaction with much more benign chemistry. As an example – also suggested in the paper above – you can replace the cathode half-cell with a copper sulfate solution with a copper electrode, with an anion exchange membrane. This would allow you to have your reduction reaction be the reduction of copper onto a copper place, which is a very tame reaction. Since the membrane only exchanges anions you would only have sulfate go to your nutrient solution, which is a benign anion in hydroponic culture. This of course means that your half-cell electrode and solution would need to be replaced with time, but this is completely independent from the control process (much more like refilling a tank of gas). The anode would only evolve oxygen in your nutrient solution, which is a potentially beneficial side effect.

Using a copper sulfate half-cell would however limit the control system to lower pH but this is not a problem since this is the most commonly used operation in hydroponics (very rarely do people have to increase the pH of their solutions).

If a proper venting system or catalytic recombination system is used on the cathode side you could also go with the simple water oxidation/reduction route and be able to increase or decrease the pH using basically, pure electricity.

I am definitely planning to build one of this setups in the future. Coupled with modern sensors and micro controllers this could make it extremely easy to maintain very fine control over the pH of the solution, compensating – in real time – all the changes in pH carried out by plants without the risk of heavily over or under compensating (as it happens when you use acid/base additions).