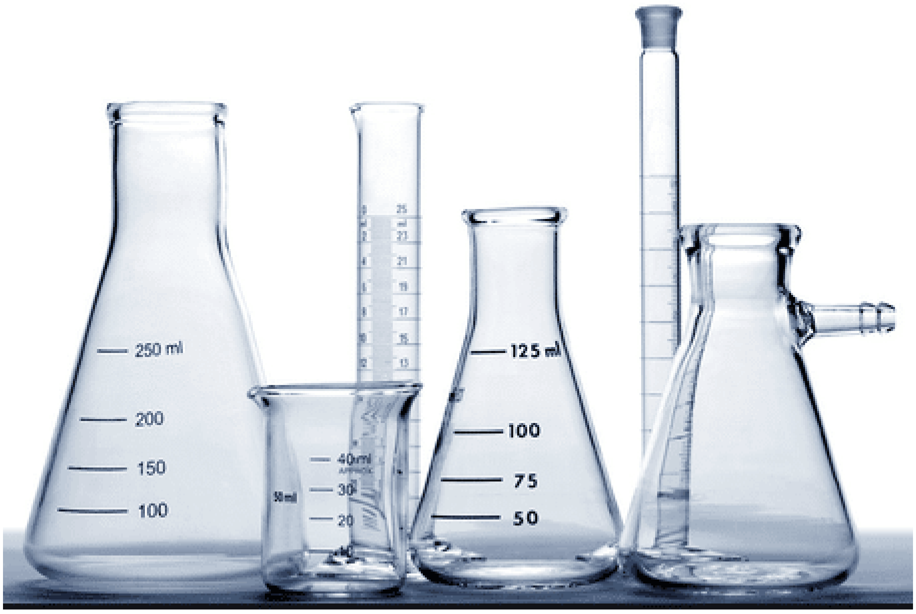
Five common mistakes people make when formulating hydroponic nutrients

It is not very difficult to create a basic DIY hydroponic formulation; the raw salts are available at a very low cost, and the target concentrations for the different nutrients can be found online. My nutrient calculator – HydroBuddy – contains large amounts of pre-made formulations in its database that you can use as a base for your first custom hydroponic endeavors. However, there are some common mistakes that are made when formulating hydroponic nutrients that can seriously hurt your chances of success when creating a hydroponic recipe of your own. In this post I will be going through the 5 mistakes I see most often and tell you why these can seriously hurt your chances of success.

Failing to account for the water that will be used. A very common mistake when formulating nutrients is to ignore the composition of the water that you will be using and how your hydroponic formulation needs to account for that. If your water contains a lot of calcium or magnesium then you will need to adjust your formulation to use less of these nutrients. It is also important not to trust an analysis report from your water company but to do a water analysis yourself, since water analysis reports from your water company might not be up to date or might not cover the exact water source your water is coming from. It is also important to do several analyses per year in order to account for variations in the water composition due to temperature (which can be big). Other substances, such as carbonates and silicates also need to be taken into account in your formulation as these will affect the pH and chemical behavior of your hydroponic solution.



Failing to account for substances needed to adjust the pH of the hydroponic solution. When a hydroponic solution is prepared, the pH of the solution will often need to be adjusted to a pH that is within an acceptable range in hydroponics (often 5.8-6.2). This is commonly achieved by adding acid since when tap/well water is used, a substantial amount of carbonates and/or silicates will need to be neutralized. Depending on the salt choices made for the recipe, adjustments could still be needed even if RO water is used. Since these adjustments most commonly use phosphoric acid, not accounting for them can often cause solutions to become very P rich with time, causing problems with the absorption of other nutrients, especially Zn and Cu. A nutrient formulation should account for the pH corrections that will be required and properly adjust the concentration of nutrients so that they will reach the proper targets considering these additions.

Iron is chelated but manganese is not. It is quite common in hydroponics for people to formulate nutrients where Fe is chelated with EDTA and/or DTPA but manganese sources are not chelated at all, often added from sulfates. Since manganese has a high affinity for these chelating agents as well, it will take some of these chelating agents from the Fe and then cause Fe phosphates to precipitate in concentrated solutions. To avoid this problem, many nutrient solutions in A/B configurations that do not chelate their Mn will have the Fe in the A solution and then the other micronutrients in the B solution. This can be problematic as it implies the Fe/other micro ratios will change if different stages with different A/B proportions are used through the crop cycle. In order to avoid this issue, always make sure all the micronutrients are chelated.

Not properly considering the ammonium/nitrate ratio. Nitrogen coming from nitrate and nitrogen coming from ammonium are completely different chemically and absorbed very differently by plants. While plants can live with solutions with concentrations of nitrogen coming from nitrate as high as 200-250ppm, they will face substantial toxicity issues with solutions that contain ammonium at only a fraction of this concentration. It is therefore quite important to ensure that you’re adding the proper sources of nitrogen and that the ratio of ammonium to nitrate is in the ideal range for the plants that you’re growing. When in doubt, plants can survive quite well with only nitrogen from nitrate, so you can completely eliminate any additional sources of ammonium. Note that urea, provides nitrogen that is converted to nitrogen from ammonium, so avoid using urea as a fertilizer in hydroponic.

Not considering the media composition and contributions. When growing in hydroponic systems, the media can play a significant role in providing nutrients to the hydroponic crop and different media types will provide nutrients very differently. A saturated media extract (SME) analysis will give you an idea of what the media can contribute and you can therefore adjust your nutrient solution to account for some of the things that the media will be putting into the solution. There are sadly no broad rules of thumb for this as the contributions from the media will depend on how the media was pretreated and how/if it was amended. It will often be the case that untreated coco will require formulations with significantly lower K, while buffered/treated coco might not require this. Some peat moss providers also heavily amend their media with dolomite/limestone, which substantially changes Ca/Mg requirements, as the root system

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Using VH400 sensors to build an automated irrigation setup

I have written several posts in the past about the measurement of water content in media, I have covered some very low cost and easy to use sensors that can also be plugged into Arduinos using i2c as well as some of the more accurate sensors you can get for this in hydroponics. However, there are several companies that offer more plug-and-play solutions for the monitoring of moisture in media and the setup of automated irrigation schemes using these measurements. The company Vegetronix offers moisture sensors that are insensitive to salt in media that can be plugged straight into boards that contain relays that can be used to control irrigation pumps. In this post, we will talk about these sensors, how they operate and how you could use them to automate irrigation within your growing room or greenhouse without much coding or setup efforts required. *This post is not sponsored by Vegetronix and I have no association with them*.

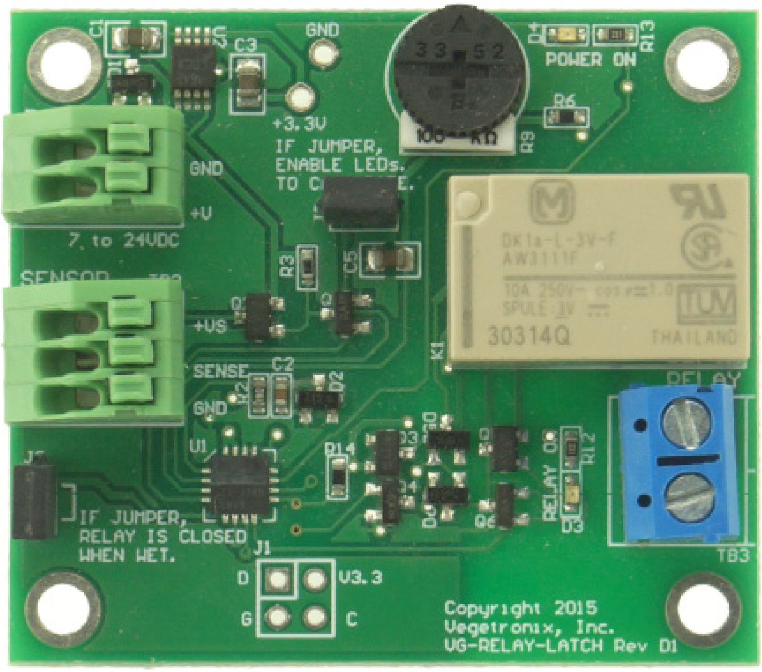
The VH400 moisture sensor

The main offering of Vegetronix in terms of moisture monitoring is their [VH400 sensor](), this sensor has the advantage of being completely waterproof and rugged in construction. It can be placed deep inside media – right next to the root ball – which is a huge advantage in hydroponic setups that use cocoa or peat moss and use large amounts of media per plant. The small size of the sensor also means that this will be more practical for something like rockwool compared with a sensor like the chirp, which has exposed circuity and cannot be fully submerged. In addition, the VH400 is also suitable for outdoor use. Another thing I like about these sensors is that they are analogue and can therefore be interfaced quite simply with Arduinos or other such control mechanisms, making them great for DYI. This would make them a great candidate to interface with a cricket board, which I showed in a recent post.

The technology used in these sensors is however kept secret. Given that the sensor has no exposed ceramic or metal leads, it would be fair to assume that it is capacitive in nature and probably uses a technology similar to the Chirp sensor, although it is difficult to know precisely how it carries the measurements without doing some heavy reverse-engineering of the sensors. One of its key features though is that it is unaffected by salinity, which is a key requirement for accurate measurements in hydroponics, and – given the lack of exposed metal leads – we are sure this is not a resistive sensor. Vegetronix does not seem to hold any patents on the sensor – please correct me if I’m wrong – so it is fair to assume that the technology is probably well within the well-known techniques in the field.

It is worth noting however that – although advertised as “unaffected by salinity” – it will require routine maintenance, washing with distilled water to reduce salt accumulation and recalibration to ensure it is giving accurate moisture content measurements. As with all moisture sensors, adequate calibration and monitoring of sensors is fundamental to long term success with them. I**f these sensors are not maintained they will stop giving proper readings with time**, especially if they are buried around the root zone of plants in hydroponic setups.

Another important point is that these are low cost sensors and have significant fabrication differences between them, proper and individual calibration of all sensors is required for proper quantitative use.



Vegetronix battery powered relay sensor

With the sensors in mind, we can now discuss the relay boards that make this choice quite attractive. The board shown above, which you can find here, is a battery-powered sensor that links to a single VH400 sensor to trigger a pump at a given moisture sensor threshold. All it takes to use this sensor is to perform a calibration procedure using the VH400 sensor and use the screw on the board to set the point where you want the relay to trigger. The board is 60 USD and the VH400 is 40 USD – at the shortest cable length – so with these two sensors you can set up a quite decent irrigation setup that is fully automated and battery-powered, with minimal wiring required.

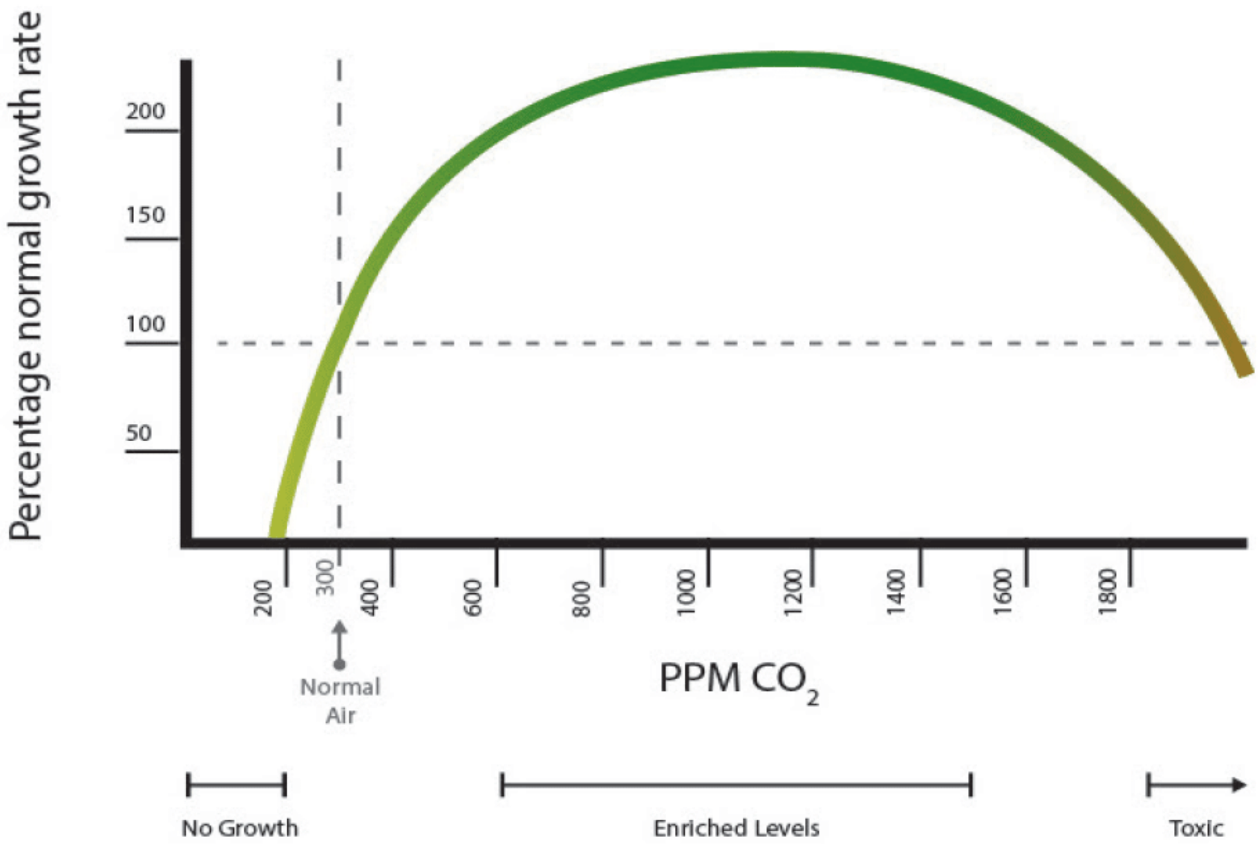
However, if you want a more extensive setup, you can get their relay hub, which can connect to popular cloud data services in order to send your data to the cloud while also being battery-powered and allowing for triggering of an irrigation system using multiple sensor readings or input from the cloud. Although this relay box is more expensive, at near 150 USD when you consider the battery accessories, it does provide you with a lot of additional options if you want access to remote monitoring of your moisture sensors. Since it can relay the data to third-party sites like thingspeak, it would be relatively easy for an experienced programmer to hook all that data into a central database to put it together with data from other sensors.

So although the Vegetronix sensors are not my preferred solution if a fully DIY setup is possible – if enough time, experienced personnel, and financial resources are available – I do believe that they make a very good value offer for those who want a decently accurate setup to monitor soil moisture content without the hassle of having to deal with the complications of a fully DIY setup. Their boards offer both super simple, low-cost solutions and more elaborate solutions for those who give more importance to data logging and monitoring. If you aren't controlling your irrigation with moisture sensors, a quick 100 USD setup of VH400+battery powered relay station is a huge step in the right direction.

Practical aspects of carbon dioxide enrichment in hydroponics

Carbon is one of the most important nutrients a plant consumes as it the largest component of a plant's dry weight. Plants get this carbon mostly from the atmosphere – in the form of carbon dioxide – and transform it through the process of photosynthesis to create carbohydrates and other carbon-containing molecules. However, carbon dioxide concentrations in the atmosphere are relatively low (350-450 ppm) so plants that are given ample light and root nutrition – such as those in hydroponic setups – will sometimes become limited by the lack of enough carbon dioxide in the atmosphere. Carbon dioxide enrichment seeks to increase this concentration in order to remove this limitation. In today's post, we're going to talk about some of the practical aspects of CO2 enrichment in hydroponics setups, such as which concentrations to use, how to do the enrichment, and when to do it.

To dive into the scientific literature about carbon dioxide, I recommend [this review](#) from 2018, which not only summarizes a lot of the relevant literature, but contains a wide array of literature resources that can be useful for anybody who wants an in-depth look at the scientific research surrounding CO_2 enrichment. A lot of the information contained in this post was taken from this paper or its sources. I will cite specific sources when this is not the case.



Taken from the [Oklahoma State University website](#) on carbon dioxide supplementation which contains some great resources on the matter.

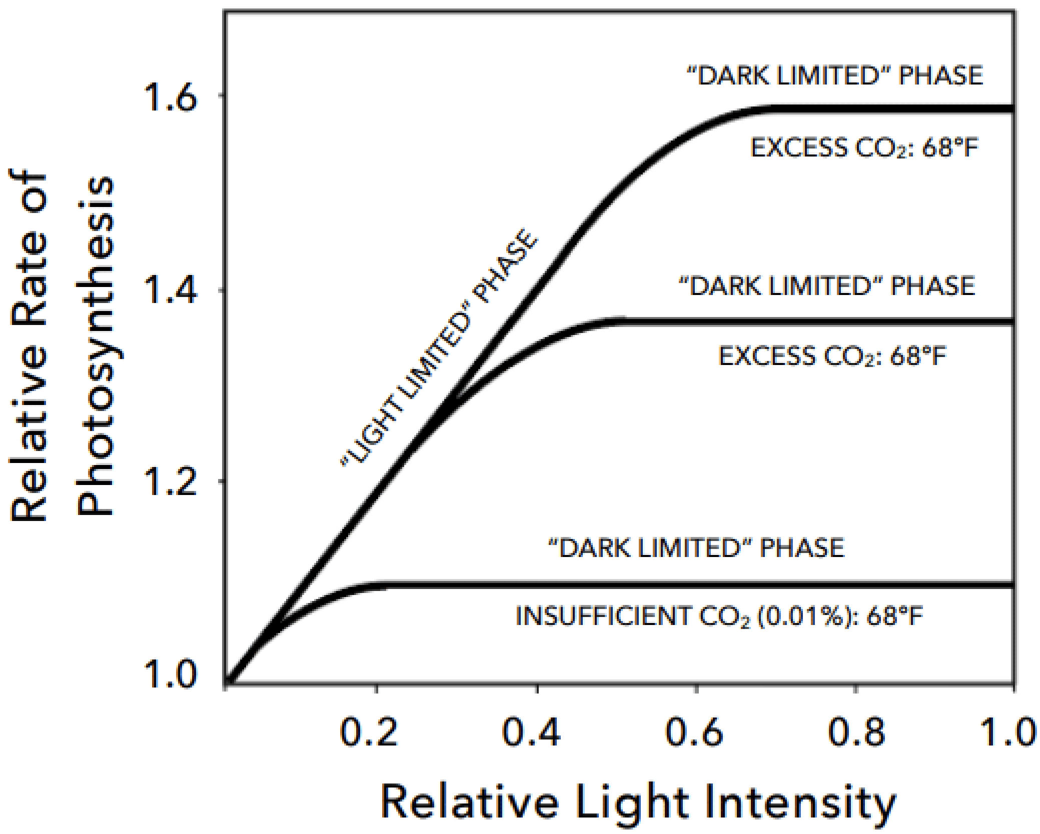
First of all, it is important to realize that carbon dioxide enrichment does not make sense under all circumstances. Plants will tend to be limited by other factors before they are limited by carbon dioxide. The first step before CO_2 enrichment is considered, is to make sure that the plants are receiving enough light (>400 µmol/m^2/s for flowering plants) and that their tissue analyses show that they are not being limited by a deficiency of any particular mineral nutrient. Plants that are either under lower light, drought stress, or nutritional deficiencies will tend to benefit significantly less from CO_2 enrichment than plants that are actually limited only by the CO2 concentration in the greenhouse. Under some of these circumstances, CO_2 injections could lead to excessive amounts of CO_2 that might lead to actually counter-productive results. Temperature can also be a key factor in determining the success of CO_2 enrichment, with temperatures in the upper range of ideal temperatures for a crop often leading to better results as the optimal temperature increases as a function of CO_2 enrichment (see here).

The next thing to consider is the source of carbon dioxide. The best source to use are CO2 canisters, which provide pure, on-demand CO_2 that can be easily controlled both in terms of its purity and its release into the greenhouse. Lower cost sources are usually preferable though, especially fossil fuel burners that will release CO_2 on demand. The issue with these burners is that they will release other gases into the atmosphere, like SO_2, CO, and NO_x, which might be harmful to plants if the output from the burner is not filtered before use. These can be minimized if natural gas burners are used, as these generate the lowest amount of these side-products. Another problem with “burners” is that they will heat the environment, if this does not coincide with the greenhouse’s heating needs it can lead to increases in temperature or excessive costs in climate control measures. For this reason, the timing of these “burner” cycles is critical to ensure they do not “fight” with climate control systems.

Illustration of gas exchange rate for different temperatures for C3 plants at 330 ppm (atmospheric) and 1000 ppm (around the max that improves the PS Rate). Taken from here.

The sensors used to detect the CO_2 and their placement will also be very important. There are mainly optical and electrochemical sensors available for CO_2 detection. Both of these sensors need to be periodically checked against CO_2 free gases and atmospheric CO_2 to check their calibration. Optical sensors often require cleaning in order to remain reliable. Because of these potential reliability issues, it is often ideal to have multiple CO2 sensors used for control and to check the values of the sensors against each other to ensure no sensors have stopped working correctly. The CO2 distribution will usually be highest close to the ground and lower at leaf canopy, reason why sensors need to be placed around canopy height, to ensure the actual canopy concentration reaches the desirable level since this is where most CO2 will be used.

In terms of the concentration that should be held to maximize yields, research has shown that the most benefits – when these are possible – are obtained when the concentration of carbon dioxide is around 1000 ppm. Carbon dioxide is not incorporated into tissue at night and is also expected to negatively affect respiration rates, so common practice dictates that CO_2 should be reduced at night to atmospheric levels to counter this problem. A 2020 study on Mulberry attempted to establish the difference between daytime and nighttime supplementation of CO_2 and found out that all of the yield increase benefits of the supplementation were obtained when CO_2 was supplemented only during the daytime.



This image illustrates the dependence of photosynthesis on light at different levels of CO_2 enrichment. was taken from here

Regarding nutrition, carbon dioxide triggers increased demand for certain nutrients. For example, nitrogen demand increases substantially when CO_2 supplementation is used (see here). For this reason, hydroponic crops that are CO_2 supplemented will usually need to be fed higher amounts of nitrogen in order to avoid losing the benefits of the CO_2 supplementation because of the inorganic nitrogen becoming a limiting factor. The carbon dioxide will increase nitrogen demand but not nitrogen absorption if the concentration is left the same, so we need to compensate for this by increasing the amount of nitrogen within the nutrient solution.

There is clearly a lot of research to be done, as optimal CO_2 supplementation involves many variables (including financial, environmental, nutritional, plant species, etc). An initial approach where the atmosphere is enriched to 1000 ppm of CO_2 with C3 plants that can take advantage of it, where nutrition, in general, is increased, temperatures are slightly increased as well and CO2 is vented at night is bound to give satisfactory initial results. This is a good starting point for anyone looking to benefit from CO_2 enrichment.

The cricket IoT board: A great way to create simple low-power remote sensing stations for hydroponics

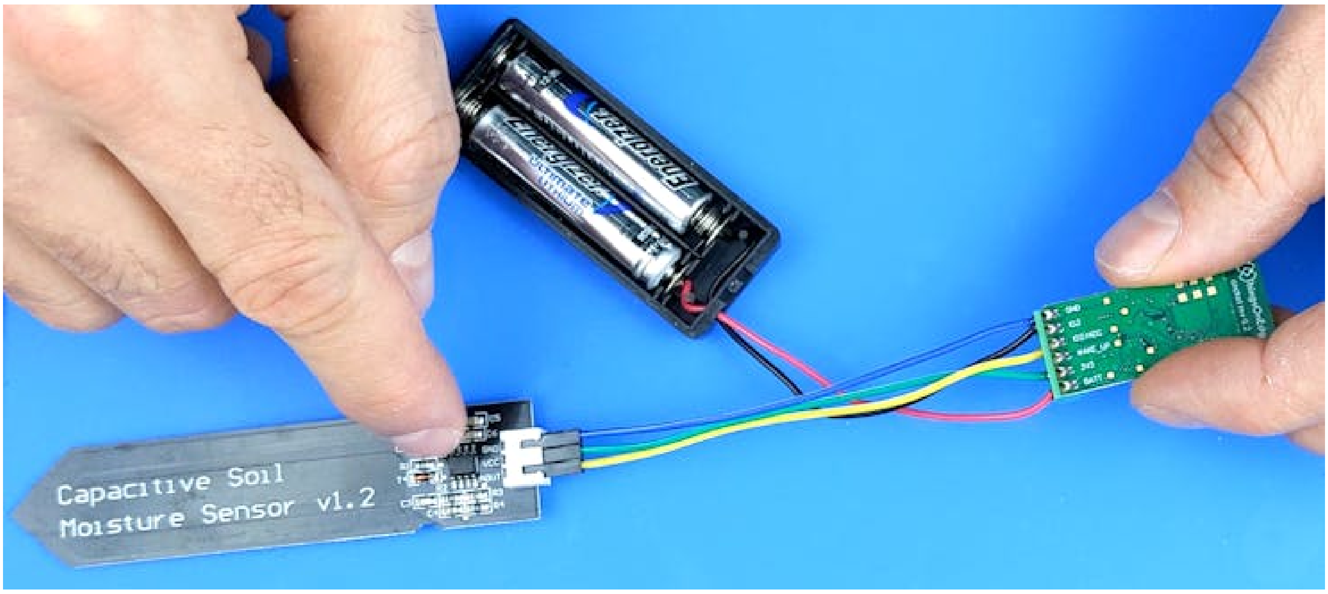
When you monitor variables in a hydroponic plant where more than a few plants exist, it becomes important to be able to deploy a wide array of sensors quickly and to be able to set them up without having to lay down a couple of miles of wire in your growing rooms or greenhouses. For this reason, I have been looking for practical solutions that could easily connect to Wi-Fi, be low powered, allow for analogue sensor inputs and be more user friendly than things like ESP8266 boards that are often hard to configure and sometimes require extensive modifications to achieve low power consumption. My quest has ended with the finding of the “cricket” an off-the-shelf Wi-Fi enabled chip that fulfills all these requirements (you can find the sensor here). Through this post, I will talk about why I believe it’s such a great solution to deploy sensors in a hydroponic environment. It is also worth mentioning that this post is *not* sponsored.

The cricket IoT board by ThingsOnEdge

When I seek to create custom monitoring solutions for hydroponic crops, one of the first requirements that comes to mind is the ability to connect through wifi effectively and be able to deliver the measurements to computers without needing wires. The cricket does this without any modifications, when you power it on it creates its own wifi hotspot that you can connect to, where you use a web interface to configure the device to connect to the normal network.

Besides connecting to the Wi-Fi, the next problem I often face is having the ability to have a proper protocol to communicate between devices. The MQTT standard has been my preferred solution – due to how easy it is to receive and relay information – so I always seek boards that are able to easily hook up to an MQTT server once they are in a Wi-Fi network. The cricket achieves this effortlessly as well, as MQTT is part of its basic configuration, which allows you to connect it with your MQTT server and relay its data right off the bat.

One of the simplest but most powerful applications for hydroponics is to hook up a capacitive moisture sensor to a cricket board and have this relay the data to an MQTT server. You can set this up to even send the data to an MQTT server powered by ThingsOnEdge, so that you don't have to send the data to your own server. This setup can be battery powered with 2 AA batteries, it can then give you readings for several months, depending on how often you want the sensor to broadcast its readings. You can read more about how to carry out this project here.



cricket hooked to a capacitive sensor, image taken from here.

One of the disadvantages of the cricket – the main reason why it won't fully replace other boards for me – is that it only has one analog sensor and one digital sensor input. This means that you're limited to only two sensors per cricket and you also have an inability to use more advanced input protocols, such as the i2c protocol that is used by a wide variety of sensors. If you lack i2c it means you're going to miss the opportunity to use a lot of advanced sensors, many of which I consider basic in a hydroponic setup, such as the BME280 sensors (see here why).

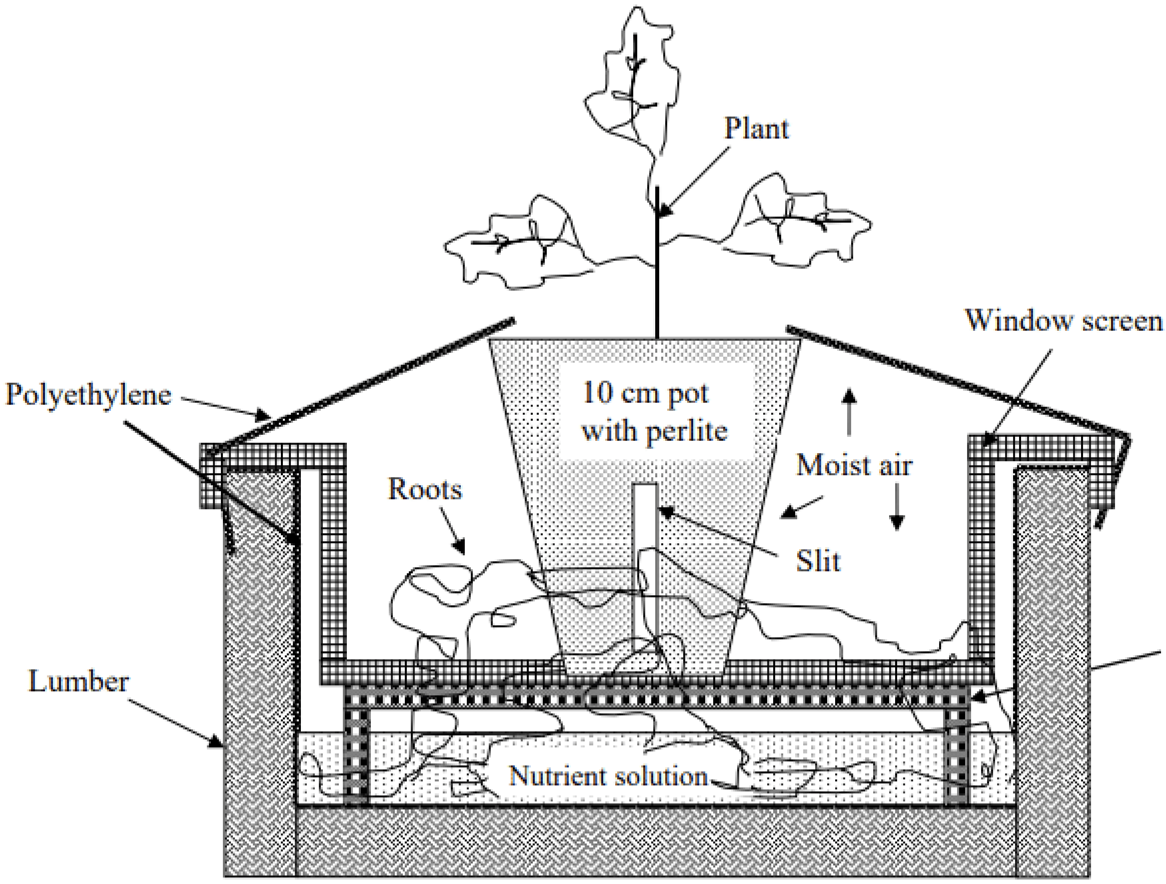
Although it is not a perfect sensor, the cricket does achieve two things that make it a great intro for people who want to get into IoT in hydroponics or those who want to setup a couple of low-power sensor stations with absolutely no hassle. The first is that it achieves simple configuration of both Wi-fi and MQTT and the second is that it simplifies the power consumption aspects, making it very easy to configure things such as sleep times, sensor reading intervals, and how often the sensor tries to relay those readings to the MQTT server. **All-in-all, the cricket is a great starting point for those who want to get going with custom IoT in hydroponics with the**

least possible hassle.

Can you grow large flowering plants like tomatoes using the Kratky method? (passive hydroponics)

I have previously shared some tips on how to grow successfully with the Kratky method in my blog before (1). This growing system, which was developed in the early 2000s, uses completely passive setups to grow plants, completely eliminating the need for any recirculation and – for smaller plants – even eliminating the need to replenish nutrient solution. However, the traditional set-and-forget methods used to grow small plants, runs into heavy limitations when confronted with the growing of larger flowering plants, like tomatoes. In this post we're going to look into these issues, some of the scientific literature on the matter and some setups that can actually be used for the growing of large flowering plants under commercial growing conditions.

In the Kratky method you place a seedling in a cup with a small amount of media on top of a large container filled with solution up to the point where the solution slightly touched the cup. The plant feeds from the nutrient solution, lowering its level and opening up an "air gap" that the plant's roots can use to get the oxygen they require. Small plants – most prominently lettuce – can be grown like this, because the crop cycle is short enough so that the amount of water in a reasonably size container can last for the entirety of the plant’s life. The effect of the plants on the solution is also milder – due to their smaller size – so nutrient imbalances created in the solution by plant absorption and plant exudates are limited.



Taken from the [2005 Kratky paper](#) on growing tomatoes passively.

With bigger plants, it’s an entirely different deal. A healthy, heavy producing tomato plant will go through 20-30 gallons of water in its entire cycle, so a simple container-based Kratky method would need to have a huge container in order to grow a plant equivalent to a plant grown in traditional hydroponic methods (think a 55 gallon drum). Trying to do this in smaller containers leads to poor results due to the changes that the tomato plant causes in the nutrient solution. Extreme changes in pH – often reaching 9-10 – and great imbalances, will hinder nutrient absorption and lead to quite extreme nutrient deficiencies and problems within the plants. In the best cases the plants will be stunted, limited in production and will yield lower quality produce while in the worst cases they will die and fail to produce any useful harvest.

It is therefore impractical to have a fully passive hydroponic system to grow tomatoes or other large flowering plants – especially if we want to rival the production potential of other hydroponics methods – but this doesn’t mean we cannot try to get close. Kratky published a [paper in 2005]() that tries to create such a system (see image above). In these systems tomatoes are not grown in containers that are perpetually left alone but they are suspended above beds where the nutrient solution rests. Nutrients are only added once – at the start of the crop – and the solution level is maintained at a desired point using fresh water. Since the volume of solution in these beds is much larger than in single containers, the tomatoes generally do much better. The tomatoes also have access to the solution that is used by many other plants, so imbalances also tend to be smaller than those of single container setups. The beds made of lumber and plastic lining are also cheap to build and provide a potentially viable way to do this commercially, although the non-recirculated solution does provide a nasty breeding ground for mosquitoes, a huge problem for this type of setup at a larger scale.

Image taken from this article.

Can you get commercially viable yields without having a 55 gallon drum per tomato plant? If you're careful! At around the same time Kratky was experimenting with his lumber beds, a group in Pakistan was trying to grow tomatoes in 13L containers using different hydroponic solutions (published here). They initially filled the container with nutrient solution but it is unclear from the paper how the solution was replenished. Since the published volumes of solution used were much higher than the container volumes, it can be assumed that water was added, but it is unclear whether this water contained nutrients or not. Since they say that the pH/EC were observed/adjusted it is reasonable to think that they maintained a certain level within the containers and measured the pH/EC trying to correct these variables with water, nutrients or pH up/down additions with time. They obtained good results with the Cooper solution but the fact that constant monitoring and adjusting was necessary shows that this technique is likely not viable for large scale commercial production as individual monitoring of plants would be a nightmare.

There is a significant lack of research after 2005 in this area, most probably because it has been established that you need to compromise pretty heavily with large flowering plants if you want to grow them without nutrient recirculation or loss of nutrient solution. Systems absolutely need to have very large solution volumes – so large growing beds are probably one of the only viable commercial choices – just because of the water/mineral demand coming from the plants. Additionally the amount of minerals drawn from the water will be large and the imbalances created by their uptake will be large as well. Furthermore, problems with large volumes of stagnant solutions are not small, accumulation of larval pests will be quite substantial and might require the addition of chemical treatments or a lot of additional mesh/netting to alleviate the problem.

If the system is not very large in volume then it becomes inescapable to deal with the toxicity of the solution, which means to adjust it accordingly. At the very least, measuring pH and EC and adjusting them accordingly is the minimum threshold to achieve results that would be acceptable at a commercial level. It is however not viable to do this at a larger scale, as the plants are heavy and having to open the containers, measure and move the plants is likely to cause damage and be very expensive in terms of labor costs.

If you don’t care about volume of production or quality that much and you just want to grow some tomato plants, then doing the Kratky method for tomatoes in 5 gallon containers with a properly formulated hydroponic solution for this purpose might yield some harvest, but the results will be very inferior to those that you could get with either a recirculating system or even a simple drain-to-waste system where the plant is just watered with nutrients with proper monitoring of the EC/pH of the run-off.

Timing irrigations with moisture sensors in hydroponics

After discussing the different types of off-the-shelf sensors for measuring moisture in hydroponics (1,2,3), we are now going to explore the practical use of these sensors to time irrigations within a hydroponic crop. In this post, I’m going to share with you some of the key aspects of timing irrigations using moisture sensors as well as some useful resources I have found in the scientific literature that discuss this problem. We will mostly discuss sensor calibration, placement, and maintenance.

Some sample curves of volumetric water content as a function of sensor output. Taken from here.

In principle, the use of sensors to perform irrigations sounds simple. Wait till the sensor tells you there is little water in the media, turn on irrigation, wait till the sensors says there is enough water, turn irrigation off and wait for the process to repeat. However, there are several issues that complicate the problem, which need to properly considered if you want to successfully use these sensors for irrigation. The first such issue is the “set point” of the irrigation – when a sensor triggers an irrigation event – and how we can determine this.

Ideally, the first thing you will do with a sensor is calibrate it for your particular media to ensure that you can equate a given sensor reading with a given moisture content. The procedure below describes how this is can be done:

1. Fill a container of known volume with drain holes with fully dry media without any plants.
2. Weigh this full container.
3. Insert the moisture sensor in it and take measurements till you have a stable reading. This will be the sensor set point.
4. Wet the media with nutrient solution until there is substantial run-off coming off the bottom.
5. Wait till the run-off stops.
6. Weigh the media and take one moisture sensor reading every 1-2 hours, recording the time of each reading, until the media goes back to within 10% of the value of the initial reading.

With this data you can plot a graph of sensor signal vs water content (measured weight – dry weight) that you can use to determine what different signals from the sensor correspond in terms of amounts of water within the media. You can translate that water weight into volumetric water content by calculating the volume of water from the weight and then diving that by the total volume of the media. You should in the end arrive to curves like the ones shown above, where you can use regression analysis to create a relationship between moisture content and the sensor signal.

With the sensors now calibrated you can now decide on a set point for the irrigation based on how much dry back you desire. The optimal point for this will depend on your VPD and your growing objectives – whether you want to save water, maximize yields, etc – but starting with irrigations at a 50% dry-back point is usually a good idea, if no other guidelines exist. Some plants species are not very sensitive to this point – see this paper on basil – provided that you allow for enough dry-back for adequate oxygenation of the root system. By allowing deeper dry-backs you can save on water, although this can be problematic if your irrigations are done with nutrient solutions of significantly high strength. The ratio of plant size to media volume will also play a role as larger plants in smaller containers will tolerate shallower dry-backs as the total amount of water in the media will be smaller.

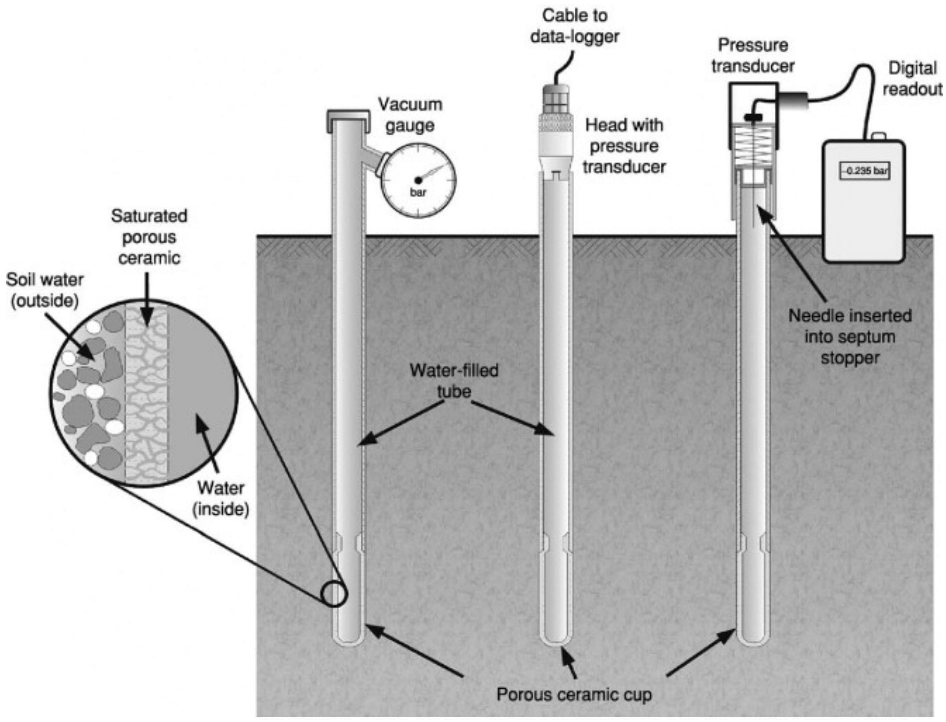
When an irrigation event is triggered it is also worth considering for how long this event will happen. If you water only till the sensor gives you a high moisture content reading, then there will be very little run-off and nutrients will tend to accumulate in the media and imbalances will be created since nutrients that are not absorbed cannot be leached out. For this reason, irrigations are usually continued for several minutes after sensors reach their high moisture reading, in order to ensure that enough run-off is collected to avoid these problems.

Sensor placement is also going to be critical for irrigation timing since you want to ensure that all plants are properly watered. Since irrigation events will generally be triggered by a single sensor, it is up to the grower to decide whether the risk of under or over watering is more acceptable. If the risk of underwatering is considered more important, the sensor will usually be placed in the plant that is largest, has the location with the micro-climate with the highest VPD, and which receives the most light. This is going to be the plant with the highest water demand and most likely the first to need irrigation, if you irrigate whenever this plant needs water, then almost everything else will be at a point of higher moisture content. This can be a dangerous game though, especially if over-watering can be problematic. In these cases, it is usually better to have multiple sensors and irrigation zones and make decisions based on more complex control processes. You can read more about irrigation timing and irrigation in hydroponics in general here.

The last important point here is sensor maintenance. Assuming that moisture sensors will always work in the same way can be a recipe for disaster because these sensors can deteriorate due to a variety of reasons. Since they are exposed to high-salinity, wet environments, contacts can corrode, leads can break and salts can accumulate within sensor structures. For this reason, it is good practice to wash these sensors with distilled water with some frequency – usually I recommend at least once per month – and to recalibrate the sensors at least once per year. I*t is also good to keep a a couple of already calibrated sensors in reserve, such that these sensors can be deployed quickly if an irrigation sensor fails*. To be safer, *have irrigations controlled by measurements taken by two sensors in the same plant* and be alerted if the measurements of these sensors diverge, this usually indicates that a sensor has deteriorated and needs to be changed.

Tensiometers (irrometers) the best way to time irrigations in hydroponics

I have recently written blog posts about the measurements of water content in media in hydroponics. The [first one] was about the problems with resistive moisture sensors in hydroponics and the [second one] showed you a low-cost capacitive sensor that does the job adequately. However, while capacitive sensors are significantly better at measuring moisture compared to resistive sensors, they are not the only type of reliable sensor that we can use to measure water content in hydroponics. In this post, I want to talk about tensiometers and how they can be used to measure water potential in hydroponics and soil. We will go a bit into how tensiometers work and why they are the most reliable sensors for irrigation timing.



Overall layout of modern tensiometers

Both capacitive and resistive sensors try to measure the amount of water in the media by measuring how the electrical properties of the media change when different amounts of water are present within it. However, plants do not care so much about how these electrical properties change but they care most about the effort that is required to move water from the media into the plant’s root system. The tensiometer is a sensor that is designed to measure the difficulty of this process. The device is built using a ceramic cup that is filled with degassed distilled water that a pressure gauge is attached to. When water is not present outside the tensiometer, the water inside of it will face a pressure to go out – causing the pressure gauge in the tensiometer to sense a vacuum – as water is added to the media, this pressure is reduced.

The above is very similar to what plants actually experience. When the media is wet, the plant has an easier time taking water into its root system, when the media is dry, the plant needs to fight in order to keep water inside of its roots from flowing into the media. Since this process mimics what the plants actually care about, it accounts for a lot of variables that can directly affect this pressure, such as the osmotic pressure of the solution and the chemical composition of the media. While resistive sensors are harshly affected by these variables and capacitive sensors are to a large extent insensitive to them, tensiometers account for them in a way more similar to how plants do.

Digital tensiometer from irrometer.com

Although tensiometers can be analogue – as shown in the first image in this post – there have been great strides in the creation of digital tensiometers that you can use to monitor your crops. The company Netafim (who did not sponsor this post and does not have any affiliation with me) provides digital tensiometers that send measurements to a central hub with data logging capabilities. Although they have been created mostly for soil, they can also be used in hydroponics to directly monitor the moisture content – or perhaps more accurately the "drying pressure" – of the media. You can also find tensiometers at irrometer.com (who did not sponsor this post and do not have any affiliation with me) where you can get both analogue and digital sensors that you can use within your custom setups, including Arduino builds. In a future post I will show you how to build such a monitoring setup. Please note that the Watermark sensor they sell is *not* a traditional tensiometer, it is a type of resistive sensor that also uses a ceramic membrane, a sort of "hybrid".

Note that tensiometers are not perfect sensors, they come with a substantial set of problems. The first is that they are going to be sensitive to salt buildup because of how water flows in and out of the tensiometers, if salt accumulates in the pores of the tensiometer's ceramic cup, it will lose its ability to properly sense the water potential of the media. This can be especially problematic if significantly hard to dissolve salts accumulate within the irrometer's structure. The second most common issue with them is their slow response, tensiometers by their very nature rely on reaching a steady state within a process that is significantly slow – water flow across a ceramic – so they will tend to respond slowly to changes in the water content of the media, as the process reaches this state.

All-in-all, if you want the absolutely best way to time irrigations of our media in hydroponics, then a tensiometer that is placed right at the root ball level of your plants will offer the best results for this, especially if you're using significant volumes of media. Tensiometers/irrometers cannot be beat when it comes to timing the watering of plants in coco or peatmoss, while they can struggle with media that are smaller, like rockwool, due to the volume that the tensiometer itself has.

The Chirp Sensor: A plug-and-play solution to moisture monitoring in hydroponics

If you want high yields in hydroponics, then you need to monitor moisture quite closely. Watering plants when they need it – and not on a timer – is critical if you want to maintain ideal water and nutrient transport within your plants. As I've discussed in a previous post, most of the cheap sensors available for this are inadequate as they are affected by the salts present in hydroponics and do not offer proper sensing of the amount of moisture in hydroponics media. Although there are a lot of different sensors that do offer adequate measurements – which we will be discussing in future posts – these are usually not easy to use and often require custom electronics, powering and sometimes complicated calibration. In this post we are going to discuss the easiest solution if you want to have adequate moisture monitoring within your crop with least possible hassle. The chirp sensor. *Note that this post has not been sponsored by Chirp's creator or anyone else.*

The Chirp moisture sensor

The Chirp sensors were created a couple of years back. They are available for purchase here. The sensors use a capacitive measuring principle, which means that the sensor detects moisture by a change in the capacitance of the media in the presence of water, rather than by a change of electrical resistance, and, therefore, the sensor is not strongly affected by the salts present in hydroponics. Additionally, the sensor plates are not corroded by the flow of current between the electrodes. The plates of the sensor are actually covered in an insulating material, giving the sensor the ability to last for a long time. The big advantage of the Chirp alarm sensor is also how easy it is to set up and how useful it can be to growers.

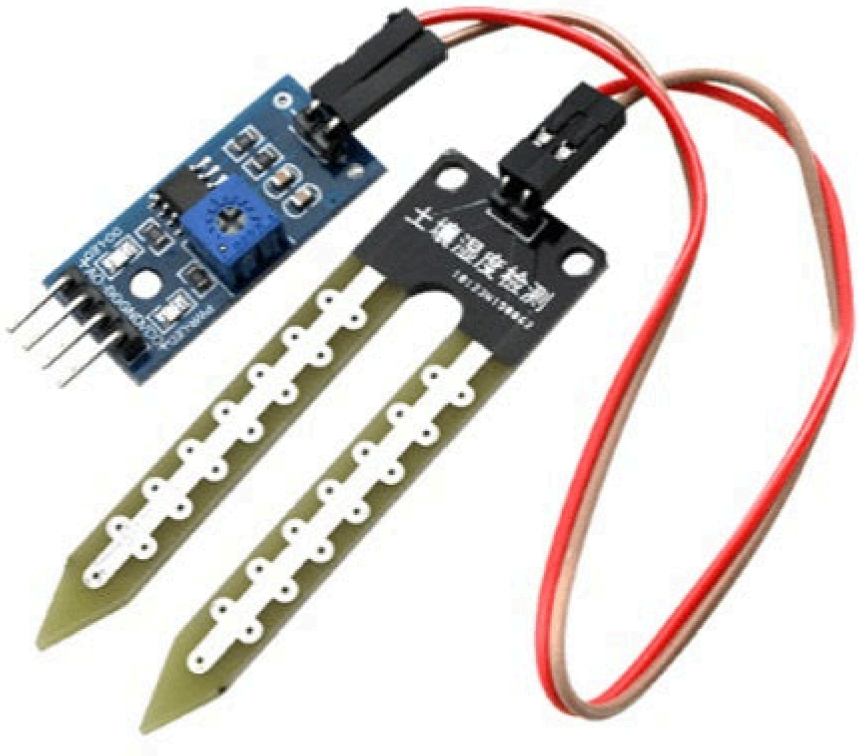
In order to set up the sensor, you will need to put it in the media at the point where the media will require watering, you then wait a couple of minutes for the sensor reading to stabilize and you will then press the button at the top of the sensor in order to indicate that this is the threshold for moisture where the sensor will start "chirping". Whenever the sensor reaches this reading again it will start chirping, chirping louder and more frequently as the moisture level drops below this point. It will also only do so when it detects light, so it will not detect the need for watering when the lights are out. **When it chirps, you water, that's it.**

If you want to figure out when to set up the sensor for watering, you can set up a pot with media (with no plants), water it till there is consistent run-off, wait for the run-off to stop, weight it – this will be the saturated weight – then weight it again every hour to quantitatively measure the dry-back of the media. You can then set up the chirp sensor when 60-70% of the water weight has been lost, which indicates a condition where watering is going to be necessary. This measurement can then be used for the watering of your plants, deeper or shallower dry-backs might be optimal depending on your conditions, but the above is a good starting point where you will not risk overwatering your plants.

The advantage of the Chirp sensor is that all of this can be done without any fancy setup, so it can be as good for watering a single plant as it could be for an entire greenhouse if enough Chirp sensors are used. Additionally, the Chirp sensors are also i2C compatible, so if you buy Chirp alarm sensors to perform this sort of monitoring you will still be able to hook them up to Arduinos or other microcontrollers in the future in order to perform your own quantitative moisture measurements and automate the entire watering cycle. **If you're looking for a low-cost, reliable yet expandable plug-and-play solution for moisture monitoring then the Chirp sensor is the way to go.**

How to identify resistive moisture sensors and why to never use them in hydroponics

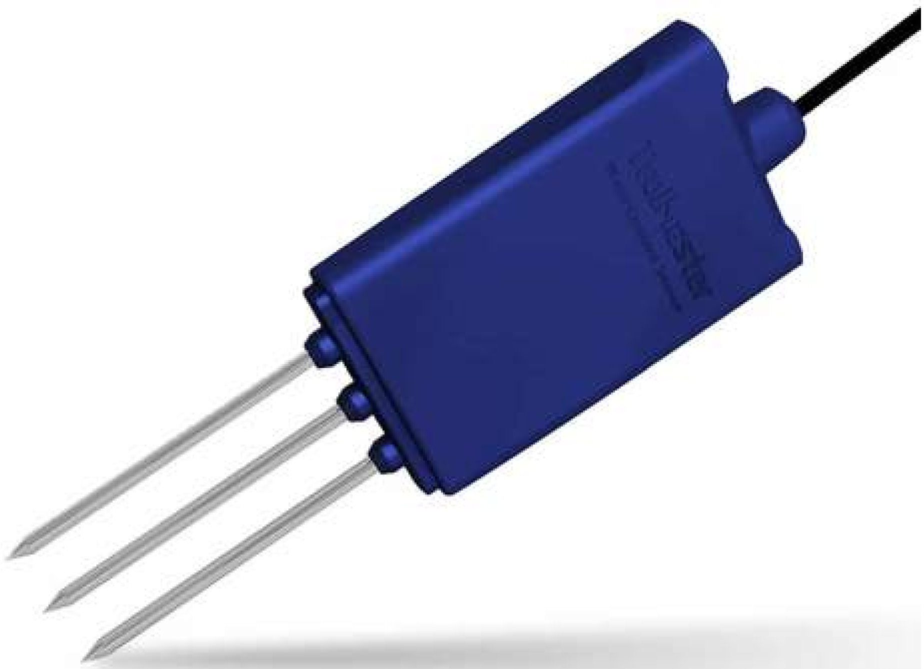
The measuring of media moisture, also known as water-content, is critical to successfully irrigating crops in hydroponics. Badly timed irrigations cause lots of the problems faced by novice and even some large scale hydroponic growers. Trying to time irrigations at regular intervals often leads to failure because of how the water demand of a plant changes with size and environmental conditions. It is therefore critical to use a quantitative input that truly represents the amount of water in the media in order to decide whether to water or not. Sadly, the most common method to do this is through the use of resistive moisture sensors; a type of sensor that is ill-fitted for this task in hydroponics. Through this post, I will talk about how resistive sensors work, how you can identify them and why you should never use them to measure water content in your hydroponic crop.



A typical resistivity sensor for measuring moisture content in soil/media

In order to measure the amount of water in media, we need to measure a property of the media that changes in proportion to how wet it is. One of the simplest approaches to this is to put two electrodes inside the media and measure the amount of resistance to the flow of electricity between these electrodes. This exploits the difference in conductivity between water and air. When the media is wet the electrodes will experience more current flow between them. On the other hand, when the media is dry, there will be more air and, therefore, less current flowing between the electrodes. This type of sensor, where we assume that the current flow between two electrodes at a fixed potential is proportional to the amount of moisture in the soil, is what we call a resistivity moisture sensor.

There are several problems with these measurements, especially in hydroponics. The most important is that hydroponic nutrient solutions are significantly more conductive than tap water and therefore the amount of current that flows through the electrodes of the sensor will be much larger than the amount the electrodes were designed for. Since current is flowing, chemical reactions will also happen at the electrodes, corroding them and changing the measurement of resistance with time as corroded electrodes become less conductive. Due to this fact, electrode performance will deteriorate with time and the electrodes will often become useless.



A more advanced resistive sensor that uses AC and stainless steel electrodes to avoid the durability issues faced by cheaper sensors like the one in the previous image.

Some manufacturers will try to reduce the above issue by creating electrodes using less easily corroded materials, such as stainless steel, and using AC instead of DC to measure resistivity. This might partially solve the issue of the electrodes being damaged with time but another issue arises; the conductivity of the solution is generally not constant with time as the amount of salts within the media changes. Imagine you start watering a crop with a solution that has a conductivity of 2.1mS/cm, you will then determine the measurement that corresponds to this value in the resistive sensor as “wet” but as you continue feeding salts might accumulate in the media and the conductivity in the root zone might actually be 3.0mS/cm when watering. This means that the “wet” measurement of the sensor is now greatly below the expected conductivity and therefore the sensor will fail to correctly tell you how much water there is in the media.

While resistive sensors might be able to tell between fully dry or fully wet conditions in their first use, this ability will deteriorate with time as the conductivity of the media changes or the electrodes deteriorate. Since in hydroponics we often rely on the accurate measurement of pretty specific dry back conditions in order to properly water plants, having a sensor that lacks a good degree of granularity in measuring water content is not acceptable. For this reason you should avoid sensors that use resistivity as their way to tell how much moisture there is in your media.

Thankfully telling whether a water-content sensor is a resistivity-based sensor is pretty easy. Almost all resistive sensors will contain metallic legs that are used to penetrate the media, so any sensor that uses metallic prongs like the ones showed in the two electrode examples above is most likely a sensor that uses electrical resistance to measure water-content. Sensors like this should always be avoided.

Which sensors should you use then? Within the next several posts I will be going deeper into other types of moisture sensors. I will describe other ways to measure moisture content that are better suited for hydroponics and give you some links to sensors you can get to carry out this task successfully.

Five tips to succeed when doing Kratky hydroponics

Passive hydroponic growing has become very popular during the past 10 years as it has a very low starting cost and uses no electricity. However, growing without active nutrient circulation, aeration and solution monitoring can cause significant problems, many of which can lead to crop failure. In this post I want to give you five tips that should help you with your passive growing experience and should allow you to go through your first Kratky crop with hopefully less problems.

1. It’s all about height and volume per plant. In a Kratky system, successfully growing plants requires the level of the solution to go down with time to allow the roots to develop structures to obtain oxygen from the air as the solution level drops. Have too much volume per plant and this does not happen quickly enough and the plant dies from water logging, have too little volume and the solution goes down too fast and the plant dies. The exact volume per plant and container dimensions depend on the environmental conditions – which determine the plant’s demand for water – but some rules of thumb have been established. *For your first experience, a 4 liter bottle can be used to successfully grow a head of lettuce through its entire lifetime*. You can check this and more suggestions for more complex setups in Kratky’s 2008 paper.

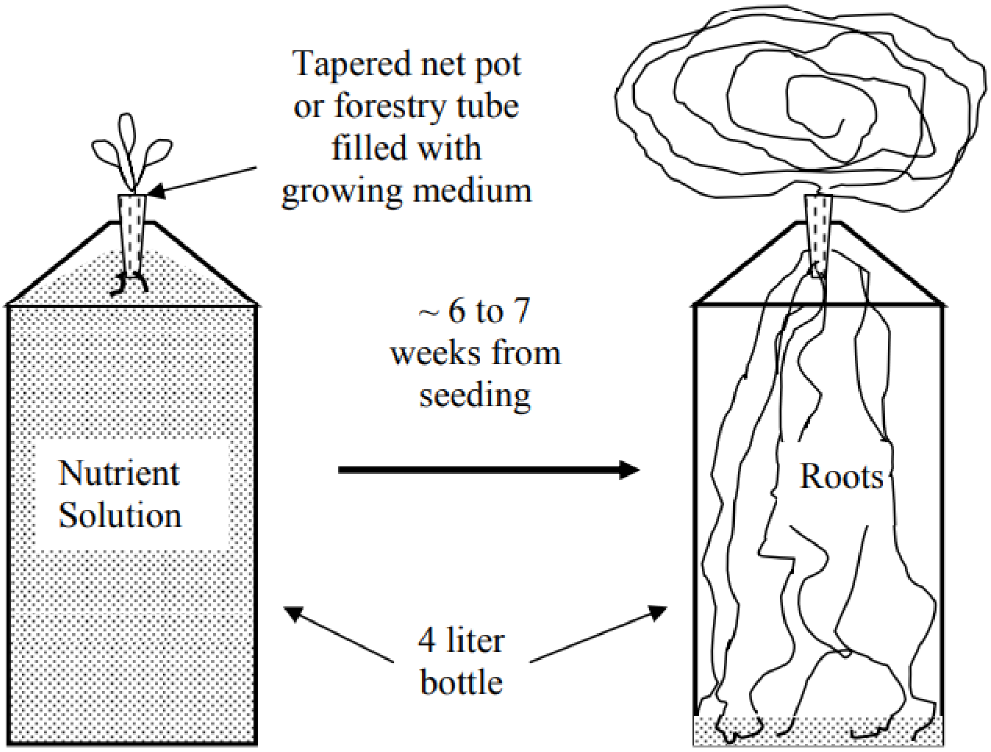


Fig. 2. Lettuce growing in a 4-liter plastic bottle.

Figure taken from Kratky's 2008 paper, cited above.

2. Be careful about the starting level. Another critical issue for a Kratky system is to make sure that the water level just barely touches the bottom of the receptacle where the seedling is placed or germinated. If the pot where the seedling resides is soaked with nutrient solution then the roots will never have access to enough oxygen and the seedlings will die. It is fundamental to allow the media where the plant is placed to wick water but to allow enough air space for the seedling at this stage.

3. Start with a lower nutrient dosage. Since the passive system will concentrate the nutrient solution as a function of time, the strength of the nutrients will go up a lot which will fit nicely with the ability of the plant to deal with more concentrated solutions. Starting with a nutrient solution that is too strong can cause the solution to become unbearable for the plant as the solution becomes more and more concentrated. This is why it is necessary to start at a lower strength. In general, starting with a solution with an EC of around 0.6-0.8mS/cm is good since the solution will become around 4-5 times more concentrated by the end of the growth cycle.

4. Starting at a lower pH can be better. Plants like lettuce will generally want to try to increase the pH of a solution as a function of time, as they will absorb nitrates more aggressively, causing the nutrient solution to become more and more basic. Lettuce can be grown at lower pH levels with fewer problems than at higher pH levels, reason why it can be beneficial to start the solution at a pH of 4.5-5.0 so that it can increase gradually and reach 7-7.5 by the end of the growing cycle.

Example of Kratky lettuce, taken from this blog.

5. Disinfect the water before preparing nutrients. The Kratky method is very vulnerable to plant pathogens due to the fact that the solution remains unchanged through the entire growing period. If the solution contains any bacteria or fungal spores, these can prosper aggressively within the growing cycle. If you’re aiming for a purely hydroponic experience with no bacteria or fungal content, you can alleviate this problem by disinfecting the solution before preparing your nutrients. *This can be done by adding a couple of drops of household bleach per liter* – allowing the solution to rest for a day after that before preparing nutrients – or by running the water through a UV treatment. Inline UV treatment filters for aquariums are cheaply available online, you only need to pass the solution through them once. Boiling the water is not something I would recommend, as this also removes all the dissolved oxygen from it, which can be hard to recover without a lot of aeration, which can reintroduce pathogens into the water.

There are many more things to consider to run a successful

Kratky setup but I hope the above tips do help you avoid some common pitfalls and establish your first completely passive, hydroponic growing method. All the above mentioned issues can get substantially harder when growing larger plants, so starting with smaller plants that are easier to handle – such as lettuce – is always a sure way to increase your chances of success.