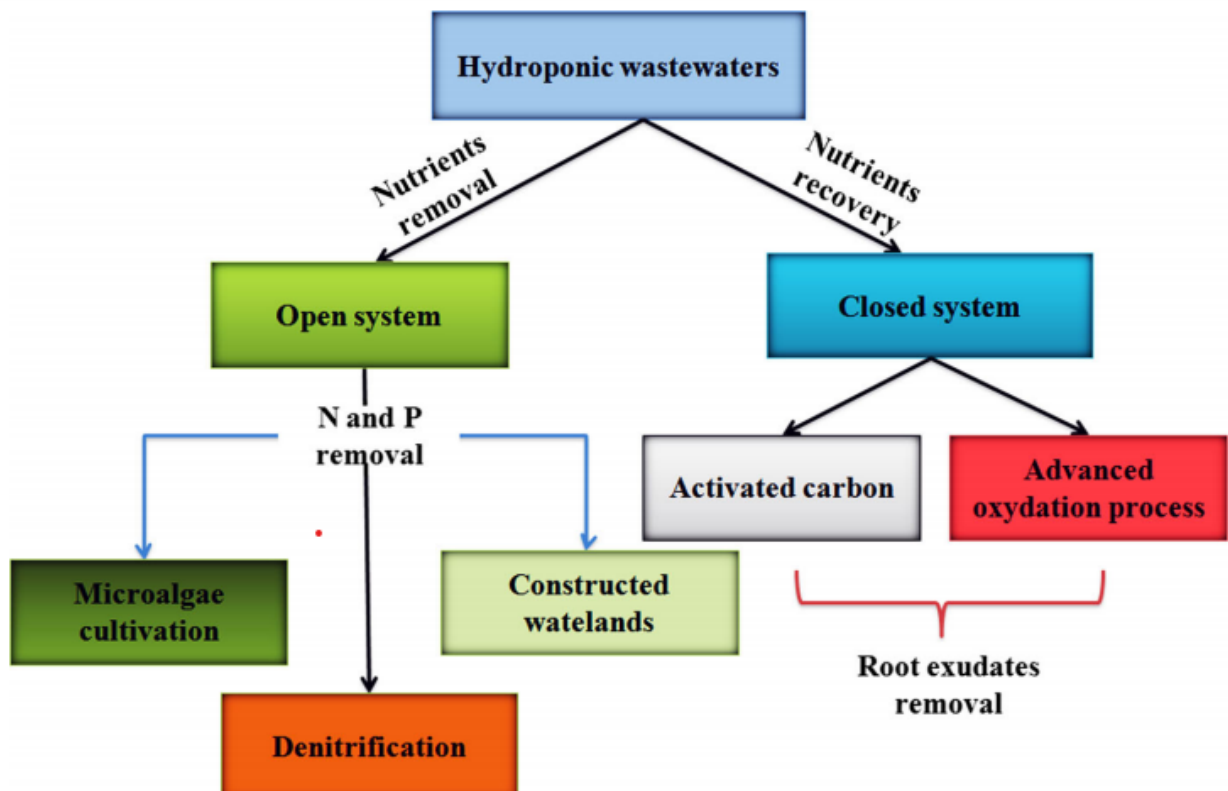


How to deal with nutrient solution waste in hydroponics

Hydroponic nutrients contain a wide array of chemicals that are fundamentally contaminating to water sources and can heavily contribute to [eutrophication](#). Both run-to-waste and recirculating systems eventually generate significant amounts of waste as nutrient solutions cannot be infinitely used – even when recirculation is done – due to the many ways in which a solution can deteriorate ([see here](#)). Because of this reason, it becomes important to figure out ways to treat this waste and ensure its nutritional content is adequately reduced before it is flushed down the drain. In this post I will go through the ways in which this can be done and which might be the more practical implementations for small/medium sized hydroponic installations. A lot of the content below will be based on information obtained from [this review article](#) on the subject.



Route for the treatment of hydroponic waste waters depending

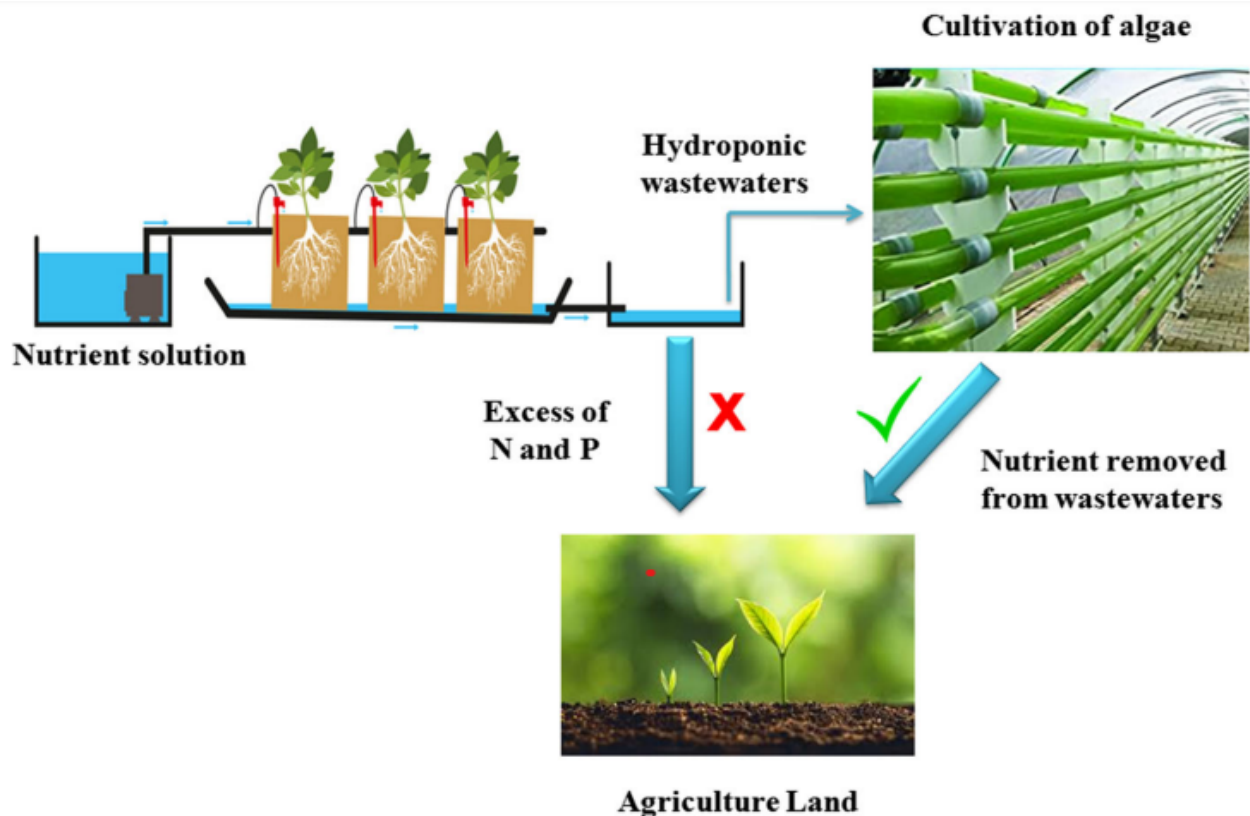
on whether nutrients are to be removed or recovered (taken from the review mentioned above). Note that eventually solutions need to be changed so the disposal of nutrient solutions cannot be endlessly avoided, even in close systems.

The main problem when dealing with hydroponic waste solutions are the nitrogen and phosphorous content, as these are normally the nutrients limiting plant growth in bodies of fresh water. A hydroponic solution where most N and P is removed can be mostly considered safe for disposal as the contaminating power of the solution will be substantially lower once these two nutrients are removed. This is why most of efforts – both in the academic literature and in real life situations – are focused on the removal of these nutrients whenever nutrient solution is to be discarded. The following are the most tested methods for the treatment of hydroponic waste solutions.

Denitrification using anaerobic organisms. In this process the solution is treated with bacteria that denitrify the nutrient solution by reducing the nitrate to nitrite and then to nitrogen gas. The process usually requires some sacrificial substance for oxidation – such as a thiosulfate or elemental sulfur granules – the process can be quite successful, removing more than 90% of the nitrogen from solutions. An issue however is that a carbon source is also needed – because the bacteria need to be fed – and this is the most important cost for this method of removal. This process also fails to address the removal of phosphorous from solution as it's mainly focused on the removal of nitrogen.

Artificial wetlands. This is the method with the lowest cost as it makes use of plants to consume all the nutrients left within the solution. It not only addresses N and P but also removes other macro and micro nutrients from the solution, generating the best effluents in terms of mineral content. Usually either common reed (*Phragmites australis*) or common bulrush (*Scirpus lacustris*) are planted and fed the waste

nutrient solution so that they can process it for a predetermined period of time before the solution is fully disposed of. This process can achieve a removal efficiency greater than 90% for both N and P. Its main disadvantage is the need for a considerable amount of space and issues working when temperatures drop significantly, as these wetlands are not built inside greenhouse environments to keep costs low.



Scheme showing nutrient removal by algae. Taken from the review mentioned in the first paragraph of this post.

Algae. In the same way as artificial wetlands, microscopic algae can also remove N and P from nutrient solutions. The algae are usually grown in transparent tubes, where the waste nutrient solution is run through. The algae can be very efficient at removing these nutrients although they will not be very efficient at removing some micro nutrients from the solution. Efficiencies greater than 90% have been achieved for both N and P removal in the academic literature. These organisms can also then be harvested in order to obtain an additional product for the hydroponic installation, which gives this process the unique opportunity to add value instead

of just being an additional cost to the grower. *Chlorella vulgaris* and *Dunaliella salina* are the two most studied algae species for hydroponic nutrient solution waste treatment.

Any waste treatment process will introduce an additional cost to a hydroponic crop. However this might not be optional in the future, as regulators in the US and Europe tighten their monitoring of hydroponic waste and restrict the amount of pollutants that might be dumped into the sewage system. With this in mind, it's good to start thinking about ways in which your hydroponic waste could be treated and what might be the lowest cost method to do so. If you have significant amounts of area then an artificial wetland might be the best method to follow while if you are short on space, algae will offer you the best method to treat your solution with a small footprint. However algae also have light needs, which means you might need to provide artificial light to them if you do not have the outdoor or greenhouse space to accommodate them.

Polluting is something none of us wants to do and ensuring hydroponic waste effluents are properly and economically treated is going to be important for hydroponic cultivation to be sustainable going forward.

Factors limiting the life of a recirculating hydroponic nutrient solution

Hydroponic systems that use recirculating nutrient solutions can be more efficient in terms of water and nutrient usage. However, despite how good the management of a solution is, there are certain factors that will limit the time that a

solution can be maintained without performing a full change of the entire recirculating nutrient solution within the system. By performing actions to attenuate some of these factors the life of the nutrient solution can be increased but trying to keep a nutrient solution endlessly is often impractical, both from a technical and economic perspective. In today's post I will talk about the factors that limit the life of a recirculating nutrient solution and some of the actions that can be taken to increase the life of the solution.

Selective nutrient uptake. Plants will uptake some nutrients significantly faster than they do others. This will lead to a substantial accumulation of certain nutrients within the solution if nutrients are replenished to keep the EC of the solution constant at constant volume. Most commonly phosphorous will tend to accumulate within the solution. This is because plants will uptake this nutrient significantly slower than the others, while it will be replenished in full strength every time nutrients are added. This will tend to increase the ratio of phosphate to other nutrients, eventually causing phosphorous, calcium and magnesium issues within the solution. Micronutrients will also be replenished more than they are consumed and micros like Molybdenum and copper can dangerously accumulate in solutions that are kept for long periods of time (months).

The above is the main reason why nutrients are often replaced every 2-4 weeks in recirculating hydroponic setups. Chemical analysis can help expand this time – by allowing the grower to selectively replace only the things that have been taken – but this requires growers to have experience in the calculation and creation of nutrient formulations and to be able to effectively adapt the nutrients as required.



A small scale, recirculating hydroponic crop

Contamination by pathogens. Nutrient solutions will get contaminated by external pathogens as they recirculate and come into contact with the media and the air. This contamination with pathogens might grow to the point that plants start developing disease, which can lead to substantial losses as diseases are spread incredibly efficiently within recirculating nutrient solutions. Potential solutions such as ozone and UV filtration can help eliminate the pathogens, but these oxidative actions will also destroy important aspects of the nutrient solution, such as the chelating agents that are used to wrap around heavy metal ions. This means that – as you destroy pathogens – you will lose heavy metal availability as it will become easier for the free metal ions to precipitate under this circumstances. When using in-line UV or ozone in a recirculating environment it often becomes necessary to be careful with the analysis and replenishing of chelated heavy metals, especially iron.

Plant root system contributions (exudates). The plants will also contribute chemicals to the nutrient solution, which will increase both the carbon content and the biological activity of the nutrient solution. These substances can severely impact

the growth and development of the plants as well, as these exudates can contain hormonally active molecules that trigger biological processes within plants. You can eliminate most of these molecules by the use of carbon filters and oxidative sterilization processes but this will cause some of the same issues mentioned in the previous paragraph about pathogen contamination. Carbon filters will also need to be checked and replaced regularly otherwise they will just fill up and become ineffective.

Accumulation of non-nutrient substances. Some ions that are added with water will not be used as nutrients and will just tend to accumulate in a nutrient solution until they become poisonous to plants. The most important accumulation problems are related with sodium and chloride in regions where water contains a significant amount of these ions (like Southern Europe, see [here](#)). This is problematic because you will always tend to add these ions with new water additions, so you have limited power to control their accumulation. This might require the use of reverse osmosis systems to add water that contains low levels of these contaminants or – often way more economically – will force the replacement of the solution at some point. Note that poisonous heavy metals – like As, Hg, Cd – can also accumulate with time, reason why the life of a nutrient solution should always be limited, regardless of the efforts made to never replace it. Impurities in your salt inputs can also play an important role in contributing with this non-nutrient accumulations.

I hope the above serves as a good explanation of the common factors that limit the life of a recirculating solution in hydroponics. Maintaining a recirculating nutrient solution is not just “adding water with nutrients to top it off” or “add nutrients to maintain a certain EC”, it requires a substantial amount of care in the evaluation of the nutrient evolution as ions accumulate, other are used and the plants themselves also contribute their own organic molecules to change the makeup of

the nutrient solution. In most cases, the solution to just “change the solution every 2 weeks” is just the most economically viable answer but this can be undesirable if both water usage and contamination of water resources wants to be minimized. With good management, solution lifetimes can often be extended to 8-16 weeks, but going beyond that can be risky due to aspects of ion accumulation that are hard to control (as those mentioned in the last problem).

Preparing your own low cost A+B generic hydroponic nutrients at a small scale from raw salts

In a [recent post](#) about the cost of custom hydroponic nutrients, I talked about the cost of preparing nutrients equivalent to those of a commonly used brand (general hydroponics Flora series) at a small scale. We saw that the cost savings are not very significant when doing this with small amounts of salts, given that the cost of the salts only drops significantly at larger scales. However there are low cost alternatives to prepare viable hydroponic solutions. In today's post I want to write about the DIY preparation of hydroponic nutrients and how you can do this from raw salts to arrive at a generic formulation that you can use for flowering plants.

Substance Name [click for url]	Formula	Mass (g) [Edit to fine-tune]	Preparation Cost
B - Potassium Monobasic Phosphate	KH ₂ PO ₄	10.985	0.5
B - Ammonium Sulfate	(NH ₄) ₂ SO ₄	2.331	0.1
B - Magnesium Sulfate (Heptahydrate)	MgSO ₄ ·7H ₂ O	31.694	0.1
B - Potassium Sulfate	K ₂ SO ₄	25.698	0.5
B - CH - micro	Ch micro	2.225	0.1
A - Calcium Nitrate (ag grade)	5Ca(NO ₃) ₂ ·NH ₄ NO ₃ ·10H ₂ O	68.705	0.5

Element	Result (ppm)	Gross Error	Instrumental Error
N (NO ₃ -)	158.296	0%	+/- 0%
K	235	0%	+/- 0%
P	40	0%	+/- 0%
Mg	50	0%	+/- 0%
Ca	208.863	0%	+/- 0%
S	150.686	0.5%	+/- 0%
Fe	2.492	0%	+/- 0%
Zn	0.142	0.3%	+/- 0%
B	0.463	0%	+/- 0%
Cu	0.039	0.4%	+/- 0%
Mo	0.018	-1.1%	+/- 0%
Na	0	0%	+/- 0%
Si	0	0%	+/- 0%
Cl	0	0%	+/- 0%
Mn	0.712	0%	+/- 0%
N (NH ₄ +)	20	0%	+/- 0%

Total Cost is 1.8

Values calculated for the preparation of 0.25 liters of A and 0.25 liters of B solution. Please use 4mL of A and B within every Liter of final solution

Predicted EC Value

EC=2.246 mS/cm

Stock Solution Analysis

Nutrient Ratio Analysis

Detailed Per Substance Contribution Analysis

Generic A+B formulation prepared using

The formulation shown above is meant to be a low cost formulation that is close to a Hoagland solution in as many nutrient concentrations as possible, using as few inputs as possible. The concentrated solution is meant to be prepared in distilled water and it is meant to be used in R0/distilled water as no mineral contributions from the incoming water have been taken into account for its making. The solution is prepared at a 250:1 concentration factor, meaning that a gallon of A and a gallon of B can be used to prepare 250 gallons of final nutrients. This is a concentration factor pretty similar to that of the General Hydroponics Flora series, with an intended dosage of around 15mL/gal of A + 15mL/gal of B. At this dosage the EC is expected to be around 2.2 mS/cm (but this should be experimentally determined!). With 250mL of concentrated solution you can prepare up to

62.5L of final solution (~16.5 gallons).

Note that I have decided to use a “chelated nutrient mix” instead of preparing a solution adding micros one-by-one, as this is not very convenient for people new to nutrient solution preparation, plus, some micros are only available in relatively larger quantities that are unnecessary to store for someone who is only interested in the preparation of small amounts of nutrient solution. The above preparation has a cost of around 25 USD/(gal A+ gal B), which is less than one third the cost of one gallon of Flora series. This cost will be significantly lower if you buy the fertilizers in larger quantities and/or if you buy all the micros and weight them independently.

To prepare this accurately at a small scale – as shown in the image above – you will need the following materials and chemicals:

- [Class A Volumetric Flask \(250mL\)](#)
- [Beaker set](#)
- [A scale adequate for this range \(+/- 0.01g , max 500g\)](#)
- [Customhydronutrients chelated micro mix](#)
- [Calcium nitrate](#)
- [Ammonium sulfate](#)
- [Epsom Salt](#)
- [Monopotassium phosphate](#)
- [Potassium sulfate](#)
- Distilled water
- air-tight 250mL Glass container for storage

You can follow this process to prepare the nutrients:

1. Prepare a clean and dry 250mL beaker, wash with distilled water (no soap)
2. Weight each raw salt on your scale, transfer to the beaker (use distilled water as necessary to ensure everything is transferred)

3. Add more water and heat – if necessary – to ensure everything is dissolved (add less than 200 mL of water)
4. Transfer the liquid to the volumetric flask (use distilled water as necessary to ensure everything is transferred)
5. Take to the final volume using distilled water and homogenize
6. Transfer to the final storage container

I have also made a video to show you how this entire preparation process is carried out, which I will be sharing shortly! Note I used a potassium sulfate I had previously purchased, which was of significantly low purity (mined potassium sulfate), the link above is for a refined potassium sulfate source, which should give you significantly less problems than it did for me and lead to higher quality solutions (my B solution was cloudy and contained some solids, which were impurities from the potassium sulfate).

If you want to prepare these solutions at a larger scale, then you will face other problems. For example how to accurately measure the final volume of these solutions. **Lines in tanks and buckets are terrible volume indicators**, flow meters also are also not enough since the salts take a very significant amount of the volume as well (remember we care about the volume of water+salts!). How to properly mix, homogenize, heat and dissolve larger amounts of solution is also not trivial. These are all problems we will be discussing in future posts and videos!

How to correctly prepare

dilutions from concentrated solutions in hydroponics

Accurately preparing dilutions of concentrated nutrients is no trivial task. For example, if you want to prepare a 10 gallon solution at “2mL per gallon” of a hydroponic nutrient, ensuring that you’re adding 20mL and actually having a final volume of 10 gallons is not trivial, given the inherent errors in the measurement of both the transference volume and the final volume. *If you’re using non-standardized methods to measure volume (buckets, gallon jugs or “tank markings” to measure volumes), you could be off by +/-20% the volume you want.* However you can accurately prepare dilutions at whatever volume you want by first measuring the conductivity of an accurately prepared solution at a small scale. A solution prepared using calibrated volumetric material.

The cost of reproducing the label of a commercial hydroponic fertilizer with raw salts at a small scale

Creating your own hydroponic nutrients can dramatically change the amount of money you spend in fertilizers per crop cycle. Commercial pre-blended hydroponics nutrients carry significantly high margins, so making your own nutrients can often save you a lot of money down the line. Raw fertilizer salts are not expensive at all – millions of tons of some of them are produced per year – so it is quite possible to save

big amounts of money by just preparing the basic fertilizers yourself. But how much money can you save? In this blog post we will be looking at the price points of some commonly used hydroponic nutrients, I am also going to share with you the cost of reproducing the fertilizer composition specified in their label. ***Note that this is not necessarily going to reproduce the actual fertilizer, since the label information is very often not accurate*** (read this post to learn more [about this](#)), but it can give an idea about the order of magnitude of the cost difference.



Let's use the General Hydroponics Flora series, which is one of the most popular hydroponic brands use by small growers, as an example. The Flora Series has a cost of 79 USD per one pack of three (total three solution, each one gallon) (I got this price from Amazon US). This includes one gallon of FloraMicro, one gallon of FloraGro and one gallon of FloraBloom. The summary of the label information for the three fertilizers can be seen in the table below. How much would it cost to recreate a fertilizer that would reproduce this exact label information? (meaning it could be sold with the same

composition values).

To make the costs comparable I have used the costs of salts that are directly available for purchase at Amazon US, not including the cost of shipping (I also did not include it for the General Hydroponics products). These costs are therefore for relatively small amounts of the raw fertilizers, which could be realistically purchased and used by anyone, the costs are expected to be lower if salts are bought in bulk (more about this at the end of the post). Also note that the cost per gallon only includes the amount of grams per salt used to prepare each gallon of concentrated solution but does not consider if the minimum purchasable amount is significantly higher than that. The compositions I arrived to are identical to the GH label compositions within +/- 0.1%. *I have made reasonable assumptions to make my salt choices, but beware that the reported label concentrations are often purposefully misleading to make any attempts at reverse engineering from them use more expensive inputs.*

Element	FloraBloom	FloraMicro	FloraGro
N (Nitrate)	–	4.7	1.75
N(Ammonium)	–	0.3	0.25
P (P2O5)	5	–	1
K (K2O)	4	1	6
Mg	1.5	–	0.5
Ca	–	5	–
S	1	–	–
Fe	–	0.1	–
B	–	0.01	–
Zn	–	0.015	–
Mn	–	0.05	–
Mo	–	0.0008	–
Cu	–	0.01	–

Composition values (in %) from the labels of the FloraBloom, FloraMicro and FloraGro fertilizers from the GH Flora series. For the FloraBloom bottle – the least complicated of the three – I have used 4 different salts to reproduce the formulation, which gives me a final cost per gallon of 22.1 USD. For the FloraMicro I had to use 9 different products, with a total cost of 24.7 USD per gallon of solution. Finally, for the FloraGro I ended up using 6 different salts, with a total cost of 24.7 USD per gallon of solution. Adding all of these up, the total cost to prepare three gallons of fertilizer with the same composition as mentioned in the General Hydroponics labels would be 71.5 USD, which is surprisingly not that big of a saving from the retail cost of 79 USD for the three gallons. *At a retail scale, the savings are not very evident, given that we're purchasing more expensive, small packages of raw salts.*

The most expensive fertilizer salt I used had a cost of 12.8 USD/gallon in the FloraBloom, at a retail cost of 0.04 USD per gram of salt. However, if you bought this salt in a larger amount (5 pounds instead of the 1 pound bag in amazon), the cost would drop to 0.01 USD/gram of it, it can drop even more if you buy it at a larger scale (>25 pounds). As the scale grows, so does the drop in the cost of these salts, if you are willing to spend moderately large amounts of money – say 1000-2000 USD in raw salts – the cost of exactly reproducing something like the GH Flora series label composition could go below 10 USD for the three gallons. ***This shows you that scale is very important when making concentrated fertilizer solutions since the price per gram of fertilizers drops dramatically as we go to larger volumes.***

With that said, the biggest savings can be achieved, *NOT* by copying a commercial nutrient solution's label, but by instead designing a fertilizer formulation that best feeds your needs and that uses the inputs that make the best sense for your growing situation and budget. This is why I encourage you to

think about creating your own formulations by thinking about your needs, rather than attempting to copy something like the GH series, which might be less cost effective and more complicated for a small grower.

Starting a youtube channel to teach chemistry related hydroponic skills

The ScienceInHydroponics blog has been a great place to share my knowledge and experience in hydroponics during the last 11 years. However, the world has changed a lot since then and video has now become easier to produce and a better way to share a lot of practical content. For this reason I have decided to start the [Chemisting youtube channel](#) where I will be sharing chemistry related content. For starters this will be mostly about practical skills in hydroponics – things like properly measuring large and small volumes, properly preparing stock solutions, taking care of electrodes, etc – but it will be expanded with videos on other topics that might eventually be outside of the realm of hydroponic culture.

The following is our first video – my wife has been instrumental in creating this channel and the video – where I share the proper technique to prepare a concentrated solution at a small scale. The video shows how to accurately measure volume and weight and how to carry out the transferring processes necessary. **Please don't forget to like, subscribe, share and suggest any topics you would like to see in future videos!**

The Scienceinhydroponics blog will continue to be updated

frequently though, as I continue to enjoy sharing blog articles with hydroponic growers around the world!

Hardware for building a wifi-connected DIY monitoring/control system for a hydroponic crop

Success in hydroponic systems can be increased by having adequate control over a wide array of different variables. Having automated monitoring and control will mean faster reaction times and provide better information about crop cycles as they happen. Having the possibility to choose the sensors that you require and code the control algorithms yourself will also provide much more flexibility when compared with commercial solutions, although the price can often be higher since you are going to get hardware that has capabilities that will likely exceed the minimal capabilities required to perform the specific setup you will arrive at. In today's post I want to talk about the hardware I generally use to build a basic DIY monitoring/control system that involves no soldering and allows for easy connections of all sensors. I will talk about each piece, its cost and why/how it's needed within a basic system.

[Raspberry Pi 4 – 39.61 USD](#). This is going to be the computer that will be the brain of the entire operation. The Raspberry Pi will receive information from all the sensors around and will make control decisions that will then be sent to the appropriate control-executing stations within the network, it

will also record sensor readings and provide a proper interface for the management staff. Usually I use the raspberry Pi to host the database that contains all the sensor readings, plus the execution of the control algorithms and the hosting of web server that the people who manage the crop can access from their other devices (in order not to have to access the raspberry pi directly all the time).



The raspberry Pi 4 computer. Note that you will need a power supply cable and SD card as well, which are an additional cost to the above.

[Arduino UNO WiFi REV2 – 39.96 USD](#). These arduino boards are going to be the heart of the sensing stations and the stations that execute control actions. They will take sensor readings and send them back to the Raspberry Pi via the wifi network. When I build DIY solutions of this type I usually use the MQTT protocol to communicate between the Raspberry Pi and the Arduinos, for this reason it's really convenient to have the Arduinos include Wifi themselves, so that additional money does not need to be spent on WiFi chips for them. With the

Arduino UNO WiFi REV2 you will have all the WiFi connectivity you need available from the get-go, with the ability to still use all the shields an Arduino UNO can support.

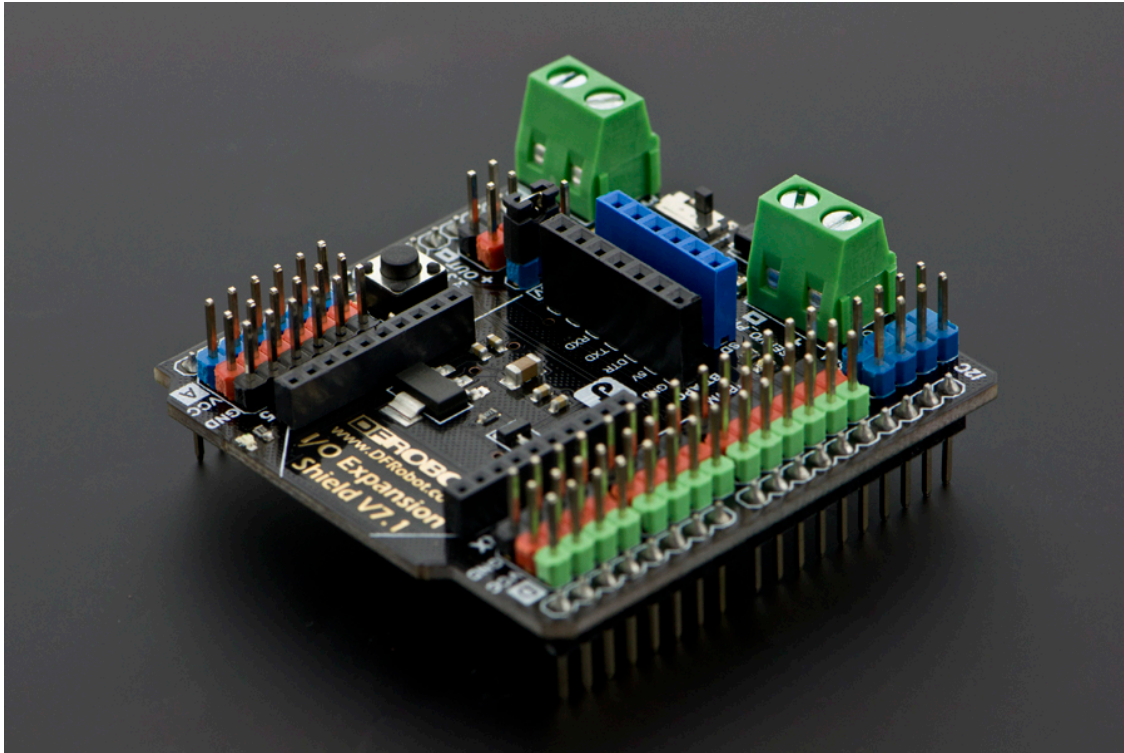
[Whitebox labs Tentacle shield – 127 USD](#). This arduino shield offers you the ability to implement measurement of several different sensors in your hydroponic crop. With this shield you can connect up to 4 different Atlas probe sensors, with all the measurements being properly electrically isolated, allowing you to place all the different probes in the same tank.

[Atlas pH kit – 164 USD](#). This is the pH probe sensor and EZ0 board that are required to be able to connect an Atlas pH probe to your Whitebox labs Tentacle shield above. This pH probe is of very good quality and will provide good readings even if the probe is immersed for a significant period of time. I have used these probes successfully for constant monitoring of recirculating solution tanks, with the probes having to be recalibrated every few months and so far no probes having to be replaced. However, if you want a probe that will withstand a lot of additional stress, then the [industrial Atlas pH probe](#) might be a better choice. The kit also includes the calibration solutions necessary to setup the probes.

[Atlas EC probe conductivity kit – 239 USD](#). This contains the necessary materials to connect an EC probe to the Whitebox Tentacle shield. The kit also includes all the necessary calibration solutions to setup the probe, it is analogous to the pH kit mentioned above.

[Gravity IO Expansion shield for Arduino – 8.90 USD](#). This shield provides you with a lot of additional plug-and-play IO capabilities for your Arduino UNO sensor/control stations. I generally use these shields to be able to easily connect digital/analogue sensors and relays from dfrobot. It is very easy to do and does not require the use of any soldering or

proto-boards. When you couple the use of these shields with project boxes you can come up with some very robust and practical DIY implementations that are easy for anyone to create.



The Gravity I/O shields are an incredibly versatile tool to connect sensors/relays to an Arduino sensing/control station

[Gravity quad motor shield for Arduino – 14.90 USD](#). Like the above, I generally use these shields as part of control stations where I will be using motors to carry out control actions. This shield can power up to 4 small DC motors, so it is ideal to control small peristaltic pumps like the ones we generally use to move small amounts of concentrated nutrient solutions or pH up/down solutions.

[Environmental sensors \(Temperature, relative humidity, barometric pressure\) BME280 – 15 USD](#). These sensors are my all-time favorites for measuring temperature, humidity and barometric pressure in hydroponic crops. They have one of the most accurate low-cost chipsets to measure humidity and this DFRobot package is extremely easy to plug into the DFRobot I/O shield mentioned above (just plug the connector into a digital input row!).

[**Analog infrared carbon dioxide sensor – 58 USD**](#). These sensors have been my go-to solution when it comes to measuring carbon dioxide concentrations. They are fairly accurate and can tell you if you are circulating air enough or if your carbon dioxide enrichment is working as expected. I usually equip at least one of the environmental sensing stations I setup with one of these sensors so that I can keep an eye on the crop's average carbon dioxide level.

[**Capacitive soil moisture sensor – 14.90 USD**](#). When we measure water content in hydroponic crops we are going to be placing the sensor in contact with highly corrosive and conductive nutrient solutions, so we want to avoid any water content measuring devices that use conductivity. This capacitive sensor has become my choice of sensor for the measuring of water-content, it is really easy to use and calibrate and offers the ability to monitor several different plants due to its relatively low cost.

[**Ambient light sensor – 2.60 USD**](#). This very low cost sensors are great for telling whether lights are actually on/off based on their inputs. They can also give you a crude measurement of how strong light is – if you are growing under the sun – so they can help you track if shades are needed. There are certainly more elaborate sensor, but this sensor gets the job done for a very low price.

[**120V, 5A Relay – 2.60 USD**](#). These relays are my go-to choice when having to power low power appliances on-off in a hydroponic setup. They are great to control things like fans and smaller lights. If you want to control larger lamps then I would suggest you use the [**16A relays**](#) that can handle much larger currents. As with the previous sensors/controls we've discussed, these relays can be easily plugged into the Gravity IO shield, allowing for the easy building of relay control stations.

The above are some of the pieces that I will commonly use in a

hydroponic crop for systematic monitoring/control. While some of these – like the pH/EC sensors and boards – could be replaced by cheaper equivalents, I prefer to go with more expensive parts that have better electrical isolation and properties. However, a very cool and useful sensor setup can be built with just an Arduino, a Raspberry Pi, a gravity I/O shield and a bunch of environmental sensors. Of course the above setup gives the most flexibility but significantly lower cost alternatives are possible if very specific stations want to be built or if the use of very specific sensor configurations is desired (so no gravity shields would be used and the sensors would just be soldered where needed).

Nutrient problems and foliar sprays

Nutrient related issues are common in hydroponic crops. They can happen due to a large variety of issues, including pH drifting, EC drifting, lack of proper nutrient ratios, humidity issues, temperature issues and root damage. The fact that an issue is of a nutritional nature will be evident within a leaf tissue analysis, but its correction by changing the nutrient solution's composition might not be evident, since transport problems imply that a deficiency in tissue might happen for a wide variety of reasons different than the concentration in the nutrient solution being “too low” (read [more here](#)). In today's post I will talk a bit about why the quickest path to recovery might actually be to perform foliar sprays instead of only attempting to change the chemistry of the nutrient solution.



Let's first talk a bit about nutrient transport in plants. A foliar analysis might be showing you a low level of an element like K in tissue, but this does not necessarily mean that the plant doesn't have enough access to K in the nutrient solution. All we know from a foliar analysis is that K has not been able to go into the leaves, but this doesn't automatically mean that K in solution is too low. This problem can happen if the temperature of the room is too high and the relative humidity is too low – very high VPD conditions – in which calcium and magnesium will be uptaken very aggressively and the plant will be deprived of potassium significantly. You can see this in studies like [this one](#) where it is clearly shown that the concentration of potassium in tissue is proportional to VPD more aggressively than to K concentration in nutrient solution.

The real fix to a problem like the problem above would be to lower the VPD of the environment – by reducing temperature or increasing relative humidity, depending on what's wrong – but choosing to just increase the amount of K in the nutrient solution would only lead to a minor response from the plant (because that's not the problem in this case). *If the grower makes an assumption and that assumption is wrong, then significant time would have been lost in the fixing of the problem and the leaf tissue analysis will reflect very limited progress.*

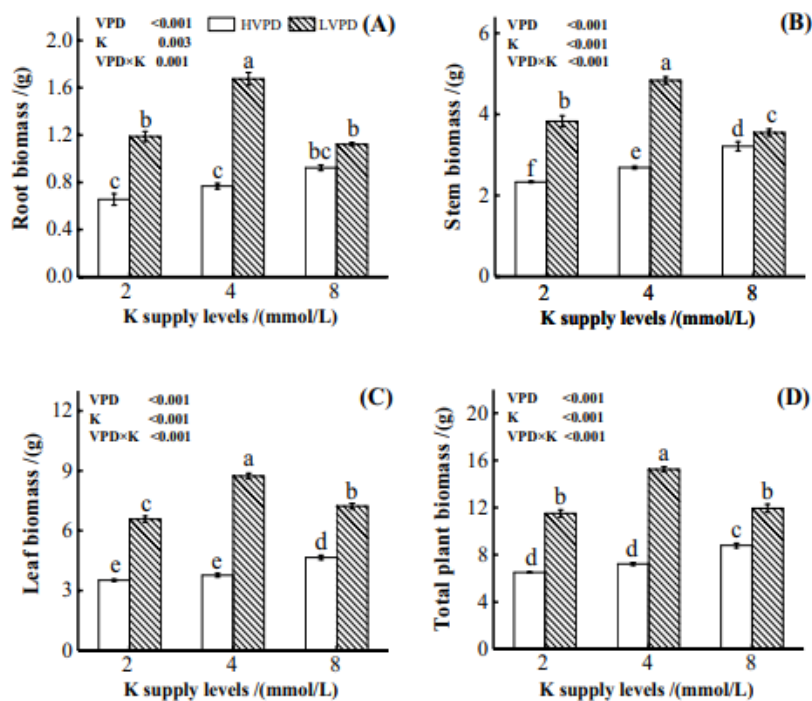


Fig. 5 Effects of vapor pressure deficit (VPD) and K supply on **a** root; **b** stem; **c** leaf; and **d** total plant biomass on day 30. Data represent the mean \pm SE ($n=5$). Different letters indicate significant differences as determined by Tukey's test ($P<0.05$). A two-way ANOVA was performed to test the effects of VPD, K supply (K) and their interaction (VPD \times K)

Image taken from [this study](#), showing the relationship between VPD conditions and K

This is where foliar spraying comes into play. In order to “hedge our bets” in the fixing of a nutritional problem, we might want to increase the supply of the nutrient available to plant leaves by applying that nutrient to leaves directly while we figure out what is wrong with the environment or the nutrient solution. This will alleviate the issue because we will be delivering the nutrient directly to leaf tissue, regardless of what the actual root cause of the problem creating the blockage in nutrient transport is. That way, if we are wrong about the fix, we will already have made some progress in fixing the problem by delivering the nutrient that we’re failing to transport where it is more strongly required.

Granted, there are a couple of caveats here. *The first is that we must have leaf tissue analysis so that we are sure about what needs to be applied (no guessing).* The second is that we

still need to look into what the root cause is and solve the issue, otherwise the foliar spraying will eventually reach a limit and be unable to completely get the plants back to full health. Think of the foliar sprays as the CPR you can give your plants while the ambulance is on the way, the plants won't be able to survive from the CPR forever, but it will help them stay alive while the true solution for the problem arrives.

Table 3

Zinc and iron concentrations ($\mu\text{g g}^{-1}$ on dry weight basis) in different parts of two cultivars of tomato plants grown at different levels of zinc with or without foliar application of zinc sulphate

Zn concentration in nutrient solution ($\mu\text{mol l}^{-1}$)	Zn concentration sprayed to the leaves (mmol l^{-1})	'Blizzard'			'Liberto'		
		Leaves	Fruit	Root	Leaves	Fruit	Root
<i>Zinc</i>							
0.15	0.00	11 a ^a	16 a	46 a	16 a	14 a	43 a
	0.35	56 c	25 b	63 a	75 c	23 b	41 a
	3.50	541 d	32 c	65 ab	630 d	30 c	71 b
7.70	0.00	33 b	30 c	162 c	36 b	22 b	96 c
<i>Iron</i>							
0.15	0.00	122 d	87 c	2333 a	111 d	74 b	1521 a
	0.35	93 b	77 b	2335 a	84 b	80 bc	2364 b
	3.50	72 a	61 a	6187 c	73 a	60 a	4660 d
7.70	0.00	97 c	85 c	3561 b	98 c	84 c	3565 c

^a Within each column, same letter indicates no significant difference between zinc treatments (HSD at 99%).

Table taken from [this study](#) showing how effective foliar applications of Zn can be in delivering the nutrient to leaves in tomato plants

To design a foliar spray to alleviate a deficiency, [first read my post](#) about some important considerations when using this technique. Second, make sure you start with lower concentrations, to prevent further stressing plants that might already be subjected to a significant degree of stress. Third, make sure you test the foliar spray on a small group of plants so that you know what the response of the plants will be before applying to the entire crop. Under some circumstances using this method might cause additional issues, so it's important to make sure the plants can take the spray before subjecting a larger number of plants to it. When doing a foliar spray to alleviate a deficiency I suggest carrying it

out only once a week initially and moving to two times per week if necessary until the root cause is fixed and the applications can be stopped.

If you are currently facing a nutrient deficiency problem and would like my help in formulating a foliar fertilizer for your specific case feel free to use the [contact form](#) or [book an hour of consultation time](#) so that we can further discuss your issue and help you fix your crop's condition.

Five things to consider when trying to copy commercial hydroponic nutrients

There are hundreds of different formulated hydroponic fertilizers out there and most of them are very expensive. Due to these very high costs, growers will often want to copy a set of hydroponic products they are very familiar with or a set of products that other growers – ideally growing under similar conditions – have had success with. However, the process of copying a commercial hydroponic nutrient with raw inputs is not as straightforward as many would like it to be and the procedure to do this accurately can be complicated due to both the nuances of the fertilizer industry and potential measures manufacturers might take to make reverse engineering of their products significantly harder. In this post I want to talk about five things you should consider before attempting to copy a hydroponic nutrient formulation, so that you can be very aware of the potential issues and problems you might find along the way.

The labels are often not accurate (enough). A fertilizer's

label contains the minimum guaranteed analysis of the fertilizer. Depending on the legislation, this usually means that the fertilizer must contain, at a minimum, this amount of every one of the specified nutrients, but there is no problem if the fertilizer contains *more* than what the label discloses. If a company is selling a fertilizer that has an NPK of 12-12-12 they can actually register that fertilizer as a 10-10-10 fertilizer and sell it as if it was a 10-10-10. The fertilizer will in reality be a 12-12-12, but the manufacturer can be sure that it will always be above the 10-10-10 specification. This is often not done out of malice, but out of the fact that the fabrication process itself might create a significant amount of variance within the composition of the actual fertilizer being produced and the manufacturer always wants to be above the minimum. This means that if you want to get the true mineral composition of the product, you'll need to send the actual fertilizer you want to copy to the lab. *Never rely on the label when copying a fertilizer.*

0 - 5 - 4
GUARANTEED ANALYSIS

Available Phosphate (P_2O_5).....5.0%
Soluble Potash (K_2O).....4.0%
Magnesium (Mg).....1.5%
1.5% Water Soluble Magnesium (Mg)
Sulfur (S).....1.0%
1.0% Combined Sulfur (S)

Derived from: Magnesium Carbonate, Magnesium Phosphate, Magnesium Sulfate, Phosphoric Acid, Potassium Carbonate, Monopotassium Phosphate, and Potassium Sulfate.

Information regarding the contents and levels of metals in this product is available on the internet at <http://www.aapfco.org/metals.htm> F-1109

This product is concentrated to the limit of solubility. Protect from freezing and direct sunlight. If crystallization occurs, mix entire contents with an equal amount of hot water and double the amount used.

Basic Applications Table

	FloraGro		FloraMicro		FloraBloom	
	1/4 tsp/gallon	33 ml/100 liters	1/4 tsp/gallon	33 ml/100 liters	1/4 tsp/gallon	33 ml/100 liters
Cuttings and Seedlings.....	1/4	33	1/4	33	1/4	33
General Purpose - Mild Vegetative...	1	132	1	132	1	132
Aggressive Vegetative Growth.....	3	396	2	264	1	132
Transition to Bloom.....	2	264	2	264	2	264
Blooming and Ripening.....	1	132	2	264	3	396

These values are intended to be used without supplements. When using supplements, please refer to genhydro.com for complete Feed Programs.

Label of a very popular hydroponic fertilizer. Trying to copy this fertilizer directly using this composition and “derived from” information, would lead to substantially higher costs,

manufacturing problems and errors. This is common to a very large array of commercial hydroponic products.

Not everything that can be claimed is claimed. When a manufacturer decides to create a fertilizer product, it might decide to leave out a specific nutrient within the formulation that is there, but that they do not want to claim to prevent reverse engineering. This is often not illegal – you're getting more than what you paid for from the point of view of the regulators – but it does mean that you're going to be completely missing something if you just copy what the label says. This is a very common trick that is done with micronutrients, where a manufacturer will claim, for example, that the fertilizer has Fe and Mn, but will make no claims about Zn, B, Cu or Mo. A person copying the label would be missing these nutrients, so their plants would end up dying from deficiencies.

The “derived from” is usually not what it's derived from. Usually a hydroponic product will contain a list of the inputs that were “in theory” used for its fabrication. This will be a list of commonly available raw fertilizers, but more often than not, fertilizer manufacturers might include a product from which the composition might be derived, that is significantly more expensive than the raw inputs that the fertilizer is actually derived from or add unnecessary inputs to the list. A simple example would be a fertilizer that is made with potassium sulfate, magnesium sulfate, and monopotassium phosphate. The manufacturer might choose to say it's derived from potassium sulfate, monomagnesium phosphate, potassium carbonate and magnesium sulfate. You can probably derive the same final composition from both salt mixes, but the monomagnesium phosphate is a very expensive input compared to the monopotassium phosphate and the potassium carbonate is unnecessary in this product and will generate pH issues. This is a very common trick, designed to make reverse engineering attempts more expensive and to difficult manufacturing for people who try to copy using this information.

Inputs with non-fertilizer components. A fertilizer can often have nutrient ratios that appear to be impossible to get to given the “derived from” section they have given. This often happens when there are inputs within the fertilizer that contain non-fertilizer components that are not reflected within the label, or even within an analysis of the nutrient solution. For example a manufacturer might decide to create a calcium supplement containing calcium nitrate and magnesium nitrate and then the label might say it has way more Ca than what is possible from just the calcium nitrate. This means there is another source of Ca present but, what is it? In this case, the manufacturer might be using something like calcium chloride, which they completely neglect to mention within the label. However you should not make assumptions about what these things are, but actually perform an analysis to try to confirm your suspicions. Often assuming the “missing part” is something like calcium chloride can lead to you formulating something that is actually toxic to plants.

Additives that are not part of the mineral makeup. Many fertilizer formulations will also contain additives that do not have any mineral content and that therefore are completely avoided within the label. This is very problematic, since the effect of some hydroponic formulations might be largely related with some of this non-mineral content. The reason why a formulation might work significantly better than another of very similar nutrient composition might be the use of some additional substances within the formulation, such as undisclosed plant growth regulators, gibberellin inhibitors or other substances with very strong effects on plants. Even things as simple as non-ionic surfactants – which can significantly increase the wetting in media like rockwool – can make a big difference between two fertilizers with the same mineral composition. Knowing that these substances are there and copying them can be quite complicated and requires a lot of relatively expensive analysis to figure out.

As you can see, copying hydroponic nutrients is not just a matter of reproducing something that mimics what the label specifies (that would be very easy). It generally requires chemical analysis of the actual fertilizer to determine its mineral composition, judicious evaluation of the available raw inputs to evaluate which ones might be appropriate to reach the required composition and special consideration about the possibility of other additives that might be present within the product and the analysis to find out what these additives might be.

Five things you can learn from leaf tissue analysis

Lab results are incredibly useful in hydroponics, as they give us a quantitative view of what's going on within our crops. From the potential array of analysis that can be carried out, few give us as much information as leaf tissue analysis. Despite this fact, few growers ever routinely carry out this analysis, as it's often perceived as unnecessary unless problems are showing up within a crop. In this article I want to talk about five different pieces of information that leaf tissue analysis can give us that can be very useful to hydroponic growers, not only when problems are showing up within the plants but as a routine measurement carried out at several different points within a plant's growing cycle.



Are the plants facing bad vapor pressure deficit (VPD) conditions. Leaf tissue analysis can tell you whether environmental conditions are pushing the plants in the wrong direction by showing you how the ratios of elements like Ca/Mg

and Ca/K are skewed. Whenever a flowering plant is grown under a hydroponic solution with a Ca/N close to 1 and the VPD of the environment is very high, the amount of Ca will tend to increase a lot relative to K. This is mainly because the transport of Ca ions is controlled in a bigger proportion by the vapor pressure deficit of the environment, so plants grown at high VPD values will tend to show high Ca in tissue. See [this paper](#), where it is clearly shown how VPD is directly proportional to Ca in tissue. At lower Ca concentrations, the difference tends to be greater between high/low VPD values.

Calcium content (mmol kg⁻¹ dry matter) of leaf margin (m) and centre (c) at two calcium levels and two vapour pressure deficits

calcium		vpd (kPa)		mean
		0.75 (l/l)	0.43 (h/h)	
16%	m	367	277	322
	c	429	390	410
64%	m	783	689	736
	c	941	920	931
mean	m	575	483	529
	c	685	655	670

VPD strongly affects Ca in tissue. Results in cucumber at two different VPD and Ca concentration levels.

Is there any heavy metal contamination going on. Growing plants for human consumption that contain a significant amount of heavy metals is usually unacceptable. This means that the early detection of heavy metal accumulation is important. Leaf tissue analysis can offer some early insights into heavy metal accumulation within leaves, in order to protect growers from getting end-products that contain large amounts of heavy metals. A plant that contains a significant amount of heavy metals in leaves before the flowering stage is not completely lost, given that heavy metals can be significantly hard to move within plant tissue. If this is detected the problem can be dealt with and inputs can be analyzed to figure out where the heavy metals are coming from. Waiting for the end-product to get a heavy metal test can be a significant waste of valuable time.

Are things where they are supposed to be. One of the reasons why it's important to carry out leaf tissue analysis routinely is that they can provide you with an idea of whether things are where they are supposed to be or not. Comparing leaf tissue analysis from a plant this crop cycle with plants from past crop cycles can give you an idea about whether things are progressing as planned or whether there are significant deviations from the past. This might be particularly important if changes are being tested or implemented and can provide an early warning about plant stress or issues that have to do with nutrient or environmental inputs.

How nutrients are changing as a function of time. When a plant shows clear visual symptoms of a nutrient deficiency, the problem is already well underway and damage to the crop's yields have already happened. In order to stay on top of things and make sure the plants are not experiencing any problems, leaf tissue analysis can help us assert whether plants are able to transport all ions adequately. Drops in elemental levels as a function of time in tissue can signal that a problem is imminently going to happen unless the situation is evaluated and measures are taken. Weekly leaf tissue analysis of a crop is a very powerful tool to track nutrient uptake and potential issues, especially if all the data is properly logged and comparisons can be easily drawn. The change in the amount of total solids within leaf tissue can also be tracked and can be used as a way to gauge whether a plant is being exposed to excessively dry conditions.

Are your silicon supplements doing their job. Silicon is very hard to transport by most plants – especially plants like tomatoes and other commercially grown flowering plants – so ensuring that the silicon you provide your plants is reaching tissue becomes important. Potassium silicate applications can often be useless if they are not being done correctly, as the life of silicate in solution is very short once the pH is reduced to the level generally used in hydroponics (5.8-6.2).

At this point silicate turns into silicic acid, which readily polymerizes to form insoluble silica chains. Doing leaf tissue analysis looking for silicon generally reveals if the applications of this element are being successful and how successful the assimilation is through the entire crop cycle.

The above are some of the ways in which leaf tissue analysis can help you improve your crop results, although they are by no means the only uses for these quantitative results. In general, leaf tissue analysis should be treated like very valuable information and judicious records of all nutritional and environmental conditions should be kept in association with them. A consistent history of leaf tissue analysis is extremely valuable in a growing facility, it helps avoid problems, carry out effective changes and quantify the real results of experimental interventions.