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	KH2PO4	10.985	0.5
B - Ammonium Sulfate	(NH4)2SO4	2.331	0.1
B - Magnesium Sulfate (Heptahydrate)	MgSO4.7H2O	31.694	0.1
B - Potassium Sulfate	K2SO4	25.698	0.5
B - CH - micro	Ch micro	2.225	0.1
A - Calcium Nitrate (ag grade)	5Ca(NO3)2.NH4NO3.10H2O	68.705	0.5

Element	Result (ppm)	Gross Error	Instrumental Error
N (NO3-)	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 (NH4+)	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 RO/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, ona 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.

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.*

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.

Why most of the time a “deficiency” in hydroponics is not solved by just “adding more of it”

I am routinely approached by hydroponic growers who believe that a “deficiency” in their hydroponic crop needs to be fixed by adding something to their nutrient solution. The logic is simple, a plant is showing some set of symptoms that are often associated with a lack of that element in tissue. The response, seems to be evident – add more of whatever is supposed to be missing to the nutrient solution – the results, often mixed whenever this is done. Why is it that a plant showing symptoms meaning it “lacks” something, is often not fixed by just adding more of that to the nutrient solution? The answer, which we will be discussing within this post, can be complicated and shows why diagnosing and *solving problems in hydroponics is not as straightforward as matching a plant’s symptoms to a nutrient deficiency chart*.

Let’s start by asking what it means to have a deficiency in leaf tissue. This means that the plant, for whatever reason, has been unable to meet its needs of some given element within its leaves. There are several reasons why this can happen. Is it completely absent, is there not enough or is it there but not able to get to the leaves because of some other reason? How do we even find out which one of these cases is the answer? For this you need to look into what is usually expected for the concentration of an element in a nutrient solution – the so called sufficiency ranges – and then evaluate whether that element is in an adequate concentration in the nutrient solution (which means getting a chemical analysis of the nutrient solution, never trust what you think is “supposed to be there”).



A potassium deficient leaf in tomato, this can often be caused by antagonistic relationships with other nutrients, exacerbated by environmental conditions

More importantly we now need to consider the ratios of that element with everything else, because plants sense both the absolute and relative concentration of the elements as the concentration of an element affects the kinetics of both its absorption and the absorption of others. For example you might have a concentration of Mg that is 50 ppm, which would be within the sufficiency range of this element and seemingly not a problem to contend with. However, if this is paired up against Ca at 200 ppm and K at 400 ppm, then that amount of Mg might be insufficient given that it's being paired against very strong competition from the other elements. In this particular case, adding more Mg might not solve the problem, because it might increase the strength of the solution to a point where the plant is stressed too much. The correct solution in this case could be to lower Ca and K to 150 and 300, so that the Mg:K and Ca:Mg are at a more acceptable level.

You can see that the cure to a deficiency is solving the transport problem, which is not necessarily solved by increasing concentration. This is also not exclusively possible with nutrient ratios, the environment can also play a

key role in determining whether transport is possible or not. Another example is a deficiency of K, despite there being 350+ ppm of K in the nutrient solution and all the ratios of the other elements with K being normal (Ca at 150 ppm, Mg at 60 ppm). In this case the problem can come from a very high temperature with low humidity, which increases the vapor pressure deficit so much that Ca transport is inevitably favored over K. This means that the plant goes K deficient, despite there being enough K, because the transport of another element is just able to out compete it due to the environmental circumstances. The solution is not to increase K, nor is it to decrease Ca. The solution in this case is to bring the VPD to an adequate level, so that the absorption of those nutrients can be normalized.

Other environmental factors can also play a key role in determining transport. For example, low nutrient solution temperature often causes a deficiency of P in plants, not because there is not enough P in the nutrient solution, because the ratios are wrong, or because the VPD is wrong, but mainly because P absorption at the root level is hindered by the low temperature. The correct solution here is not to add more P – that often makes it even worse – but actually heating up the nutrient solution to make absorption easier or – if that's not possible – it can often be helped with the establishment of beneficial fungi to help with the transport of this nutrient.

As you can see, the failure of some nutrient to show up in leaf tissue is not so commonly due to its absence in the nutrient solution but more commonly related with some other factor that is wrong. Excess of other nutrients, which causes skewed ratios, bad environmental configurations – too low/high VPD values – problems with solution temperature or solution pH are some of the most common ways in which nutrient deficiencies can affect plants without the element in question being absent in any significant way. The ultimate goal is to

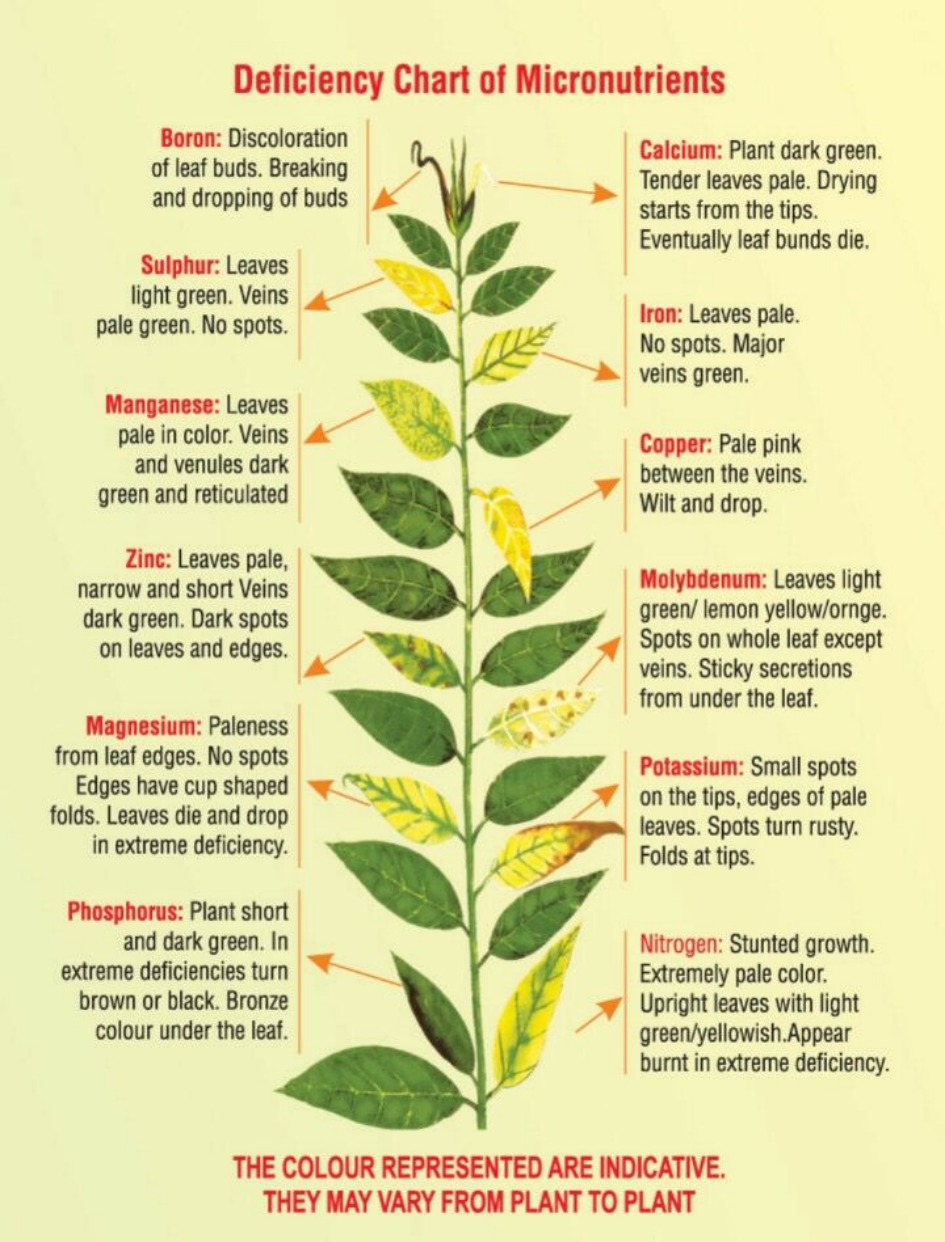
determine why the transport of an element is not working and, in doing so, eliminate the block so that the plant can again process its nutrients successfully.

Getting all the data to evaluate a problem in a hydroponic crop

Problems are an inevitable part of being a hydroponics grower. Even experienced growers will sometimes face issues when moving between environments or plant species as things change and new challenges arise. A big part of being a good grower is to be able to think about these obstacles, find out their causes and successfully respond to them. In this post I want to share with you some information about the data you should gather in order to properly diagnose a problem in your hydroponic crop. This is important as not having enough data often makes it impossible to figure out what's going on, while simple measurements can often give a very clear view of what's happening with the plants.

Take detailed, well documented pictures. What you see is a very important portion of what describes a plant's status and issues. The first thing you should do is document what you're seeing – take pictures of the plants showing the problem – and write down the symptoms you are observing. This documentation process should be organized, give each plant an ID, take pictures under natural light or white light of the new leaves, old leaves and root zones (if possible). Take pictures across different days showing the evolution of symptoms. Have all this information so that you can then better interpret what is

going on. Also remember that symptoms do not necessarily mean deficiencies and deficiency symptoms does not necessarily mean more of a nutrient needs to be added to a nutrient solution (for example a P deficiency can show under low nutrient solution temperature even if P in the solution is actually very high).



Taking detailed pictures can help assess whether a nutrient deficiency is present by gauging the changes in a plant as a function of time. However these should be confirmed with leaf tissue analysis as some of these symptoms can have causes not related with a nutrient deficiency.

Record all environmental data. When a problem happens, it is often related to the environment the plants are in. Having

recorded data about the environment is a very important part of evaluating the issue and figuring out what went wrong here. Getting a good view about the environment usually involves having measurements for room temperature, temperature at canopy, relative humidity, carbon dioxide concentration, nutrient solution temperature, PPFD at canopy, and root zone temperature. All of this data should be recorded several times per day as they are bound to change substantially between the light and dark periods.

Get nutrient solution analysis. Diagnosing a problem is all about having a complete view of what's going on with the plants. The nutrient solution chemistry can often be a problem, even without the grower knowing a problem is brewing there. Sometimes nutrient solution manufacturers might have batches with larger errors than usual, or the input water might have been contaminated with something. There is also the potential of human error in the preparation of the solutions, which means that getting an actual check of the chemistry of the solution can be invaluable in determining what's going on.

Get leaf tissue analysis. Even if the nutrient solution analysis does not reveal any problems, there are often issues with plants that are related with interactions between the environment and the solution that can go unnoticed in a chemical analysis of the solution itself. Doing a leaf tissue analysis will show whether there are any important nutrient uptake issues within the plant, which will provide a lot of information about where the problem actually is.

Critical nutrient foliar concentration for Blueberry (source: Penn State University)

Element	Deficient	Below Normal	Normal	Above Normal	Excessive
N (%)	1.65	1.7	1.9	2.1	>2.1
P (%)	0.05	0.06	0.1	0.18	>0.18
K (%)	0.35	0.4	0.55	0.65	>0.65
Ca (%)	0.35	0.4	0.6	0.8	>0.80
Mg (%)	0.18	0.2	0.25	0.3	>0.30
Mn (ppm)	45	50	250	500	>500
Fe (ppm)	65	70	200	300	>300
Cu (ppm)	4	5	11	15	>15
B (ppm)	29	30	40	50	>50
Zn (ppm)	14	15	25	30	>30

Critical nutrient foliar concentration for Brambles (source: Cornell University)

Element	Deficient	Below Normal	Normal	Above Normal	Excessive
N (%)	1.80	2.00	2.50	3.00	>3.00
P (%)	0.23	0.25	0.35	0.40	>0.40
K (%)	1.45	1.50	2.00	2.50	>2.50
Ca (%)	0.57	0.60	1.70	2.50	>2.50
Mg (%)	0.27	0.30	0.70	0.90	>0.90
Mn (ppm)	45	50	150	200	>200
Fe (ppm)	48	50	150	200	>200
Cu (ppm)	6	7	30	50	>50
B (ppm)	28	30	40	50	>50
Zn (ppm)	18	20	35	50	>50

Critical nutrient foliar concentration for Strawberries (source: Cornell University)

Element	Deficient	Below Normal	Normal	Above Normal	Excessive
N (%)	1.50	1.80	2.00	2.80	>2.80
P (%)	0.20	0.25	0.35	0.40	>0.40
K (%)	1.20	1.50	2.00	2.50	>2.50
Ca (%)	0.60	0.70	1.50	1.70	>1.70
Mg (%)	0.25	0.30	0.45	0.50	>0.50
Mn (ppm)	40	50	150	250	>250
Fe (ppm)	50	60	150	250	>250
Cu (ppm)	5	7	10	20	>20
B (ppm)	20	30	60	70	>70
Zn (ppm)	15	20	35	50	>50

Expected nutrient ranges for leaf composition of different species. Leaf tissue can often help tell whether there are some important abnormalities in progress and may help the grower assess which causes to look at.

Take well documented pictures of tissue samples using a microscope. A microscope can be important in determining what's going on with plants, because it can show developments in roots/tissue that cannot be seen with the naked eye. Microscopes can often reveal very small insects or fungal structures that would have otherwise gone unnoticed. For this reason, a microscope and the taking of microscopy images can

be of high value when dealing with a problem in a hydroponic crop.

With all the data mentioned above, most hydroponic crop problems will be much easier to diagnose. Some of the biggest failures in dealing with problems in hydroponic crops come from not gathering enough data and just guessing what the problem might be given how the plants look. Sadly plants can show similar responses to a wide variety of problems and – in the end – nothing replaces having the data to actually diagnose what's going on in order to deal with the issue appropriately. *Lacking an evidence-based picture is often the biggest difference between success in diagnosing/fixing an issue and failure or even worse problems caused by taking actions that have nothing to do with the real problem at hand.*

Five common misconceptions around nutrient management in hydroponics

After many years of experience as a consultant in the hydroponic industry and interacting with dozens of different customers growing different plants with different systems, there are some common misconceptions that become apparent as time goes by. As a chemist, the ones I remember the most are related with the management of nutrient solution and the diagnosis and treatment of nutritional problems in plants. In today's post, I want to talk about some of these misconceptions and hopefully shine light into what the more accurate interpretation of these phenomena actually is.

The EC is increasing, my plants are not feeding! One of the

concerns I most commonly address is that plants are “not feeding” because the electrical conductivity (EC) of the nutrient solution is not decreasing, but actually increasing after the solution goes through the plants. Many growers think that EC measures nutrients in a solution, so if a plant feeds on nutrients, then the EC should naturally decrease as the plant feeds. This is wrong because the plant consumes both nutrients and water and EC is a proxy for nutrient concentration and not for the absolute amount of nutrients in the water. *As a plant feeds it will absorb both nutrients and water but significantly more water than nutrients*. Remember, plants are mostly made out of water and also use water to regulate temperature, humidity and nutrient uptake, so they will take way more water than nutrients, increasing the EC as they feed. As a plant grows larger it’s nutrient and water demands grow, but the water demand grows significantly more than the mineral nutrient requirements, meaning the plant will progressively increase the EC more and more as it feeds more and more aggressively.



The plants are yellowing, there must be a nutrient deficiency. As soon as plants start to show signs of yellowing, a significant amount of growers will immediately look and try to interpret this as a sign that there is some form of nutritional deficiency. Most that subscribe to this belief

will look for pictures of deficiencies online and do their best to match what they see with a deficiency and then proceed to supplement the solution with some fertilizer that contains the "missing element". More often than not, this is actually not caused by the composition of the solution at all but by some environmental factor that is not being properly managed. In run-to-waste systems this is most commonly related with a significant pH drift in the media – reason why it is always necessary to measure pH/EC of the run-off – but it can also be related to unnecessarily harsh VPD conditions or even a lack of enough air circulation. I would say that 5/10 times, problems with the plants have virtually nothing to do with the nutrient solution at hand.

If you want more X, then increase X in the nutrient solution. The relationships between the concentration of elements in a solution and the concentration of nutrients in plant tissue is not linear. Sometimes, increasing the concentration of an element in solution can actually lead to *less* of that nutrient being present within plant tissue. An example of this can be phosphorous, a plant can suffer from a phosphorous deficiency due to the formation of insoluble iron phosphate compounds in tissue that appear when the concentration of these two elements goes above some threshold. As more of either is added, more of these insoluble compounds are formed and less of P and Fe actually gets to the plant. Another example can be Ca, where the amount of Ca in tissue is more dependent on VPD than on the concentration of Ca in solution, changing the VPD by 20% will affect Ca in tissue significantly more than adding 20% more Ca to the solution in some plant species. In these cases you might add 20% more Ca but your VPD drops 20% and you actually see a decrease of Ca in tissue. *Sadly nutrient dynamics are not simple and often a more holistic picture needs to be used to approach nutritional management!*

Plants need aggressively more phosphorous when they flower. Most commonly used fertilizers in soil tend to have higher P/K

values when they target “flowers”, this is because, in soil, phosphorous is not highly available and the supplementation of highly available phosphorous during flower can be very useful to plants. However, flowering plants in hydroponics always have access to significant amounts of soluble P and most actually do not require an increase from this base level when they go into their flowering periods. Many commercial hydroponic solutions used for tomatoes will – for example – keep their P values at 50 ppm through the entire growing period, only increasing K during the flowering period, but not P. Experiments across various commercially grown flowering species have shown that levels in the 50-65ppm range are ideal for many plants during their entire life cycle, this matches the experience of growers in the horticultural hydroponic industry.

There is a perfect nutrient solution. Many growers go on a “holy grail” quest to find the “perfect” nutrient solution that will give them the absolutely best yields. Many commercial fertilizer producers also call me asking to formulate “the best possible formulation” to grow a given type of plant or – even worse – to grow a wide variety of plants. The truth is that the ideal solution to feed a plant will depend on the genetics, the environment, the irrigation system, the growing media, etc. Due to the large amount of variability between growing setups, plant genetics and growing methodologies, more often than not, the nutrient optimization process needs to be carried out for every grower. Don’t get me wrong, a base formulation will probably get you 80% of the way to your maximum potential yields – nutrient solutions are not miracle generators, they are just food – but conquering that final 20% will require a lot of additional effort that will most likely be limited to your particular conditions. This is because most environments are limited by different factors and using the nutrient solution to help overcome some of these limitations will modify the solution in a way that’s probably detrimental for other environments.

I hope the above misconceptions show that the world of nutrient solutions and plant management is not so simple and that there is a lot that goes into understanding how nutrients interact within a plant and how a given growing environment needs to be modified in order to improve crop results. My goal is to help you expand your knowledge about hydroponics and better reach your goals by overcoming some of these misconceptions and tackling some of the true problems within your hydroponic crops.

Five tips to successfully manage your nutrient solution in a recirculating hydroponic setup

Although a significant portion of hydroponic growers use run-to-waste setups – where the nutrient solution is ran through plants and then lost – the industry is now moving towards the implementation of recirculating hydroponic systems in order to reduce both water usage and the unnecessary dumping of fertilizers into sewage systems. A recirculating setup has many advantages and can provide better yields than run-to-waste setups, provided the solution is properly managed and changed through the growing cycle. In this post I'm going to talk about five tips that will help you successfully manage your nutrient solution when using this type of system.

Ensure the volume of the reservoir is at least 10x the volume necessary for a single irrigation. The total volume of a reservoir is key in a recirculating setup because you want the

bulk of the solution to be unaffected by whatever nutritional changes are caused by the plants during each feeding. This means that you want most of the solution to be inside your tanks and not inside the media when every irrigation is done. A simple rule of thumb is to make the volume of your initial reservoir at least 10x the volume that it would take to carry out a single irrigation of your entire crop. If you do this the water and nutrient absorption effects will happen slowly and will give you time to manage your solution without any harm coming to the plants.



A recirculating hydroponic tomato system using dutch buckets

Circulate your solution until your pH and EC are constant. After an irrigation cycle starts, the solution will first mix with the remnants of the last irrigation cycle within the media, which will make the pH and EC of the return different from those of the main tank. In order to ensure that the plant's root system is being subjected to the desired nutrient concentrations, make sure you carry out the recirculating process until the EC and pH of the tank remains constant and matches the return pH and EC. Once this happens you know that the conditions within the media have now been equalized with the larger body of solution and you can stop the irrigation process. Constant monitoring of the pH and EC within the tank are therefore necessary within this type of setup.

Add water and *not* nutrients when the EC increases with every irrigation. In a normal recirculating setup the EC of the solution in the main tank will tend to increase with every irrigation while the total volume of the solution will decrease. This happens because healthy plants *always* absorb more water than nutrients, which means any measure that's proportional to concentration – such as the EC – will tend to increase as the amount of water goes down. You want to add enough water to bring the EC down to the desired EC but you do not want to add nutrients with this water and this would

increase the EC or contribute to nutrient imbalances within the solution. Note that you will need to add *less* water than the amount that was absorbed by the plants, because the plants also take some nutrients with them, meaning that the amount of water needed to reestablish the EC to what it was before will be lower. If an initial solution has 1000 gallons, the volume might go down to 950 gallons on the first irrigation but you might only need to add 20 gallons to bring it back to the original EC, making the total in the end around 970 gallons. *Make sure the pH of the tank is also corrected after every irrigation and water addition*.

Replenish water with nutrients when volume is down 40%, use this as an opportunity to shift the solution. As discussed in the last tip, the volume of solution will go down with time, even if some water is added to return to the original EC. At some point more than 40% of the volume will have been spent and it is at this point where you should fill the tank back to its full volume with water plus nutrients. You can also use this opportunity to change the nutrient ratios and skew them in the direction that you want your plants to follow nutritionally. For example in a flowering crop it is common to increase the amount of potassium during the blooming stages of the plant, so this can be done as nutrient solution is replenished after it's consumed by the plants. *Note that this process cannot be carried out indefinitely because both nutrient imbalances and plant exudates will accumulate within the main solution*. Most recirculating crops will fully change the solution every 3-4 weeks to avoid these problems although the life of the solution can be extended further when chemical analysis is done – to customize nutrient replenishing – and adequate filtering is implemented to remove substances contributed by plants.

Add in-line UV filters and carbon filters. It is fundamental to ensure no microorganisms contaminate your nutrient solution. For this reason, online UV-filters are necessary to

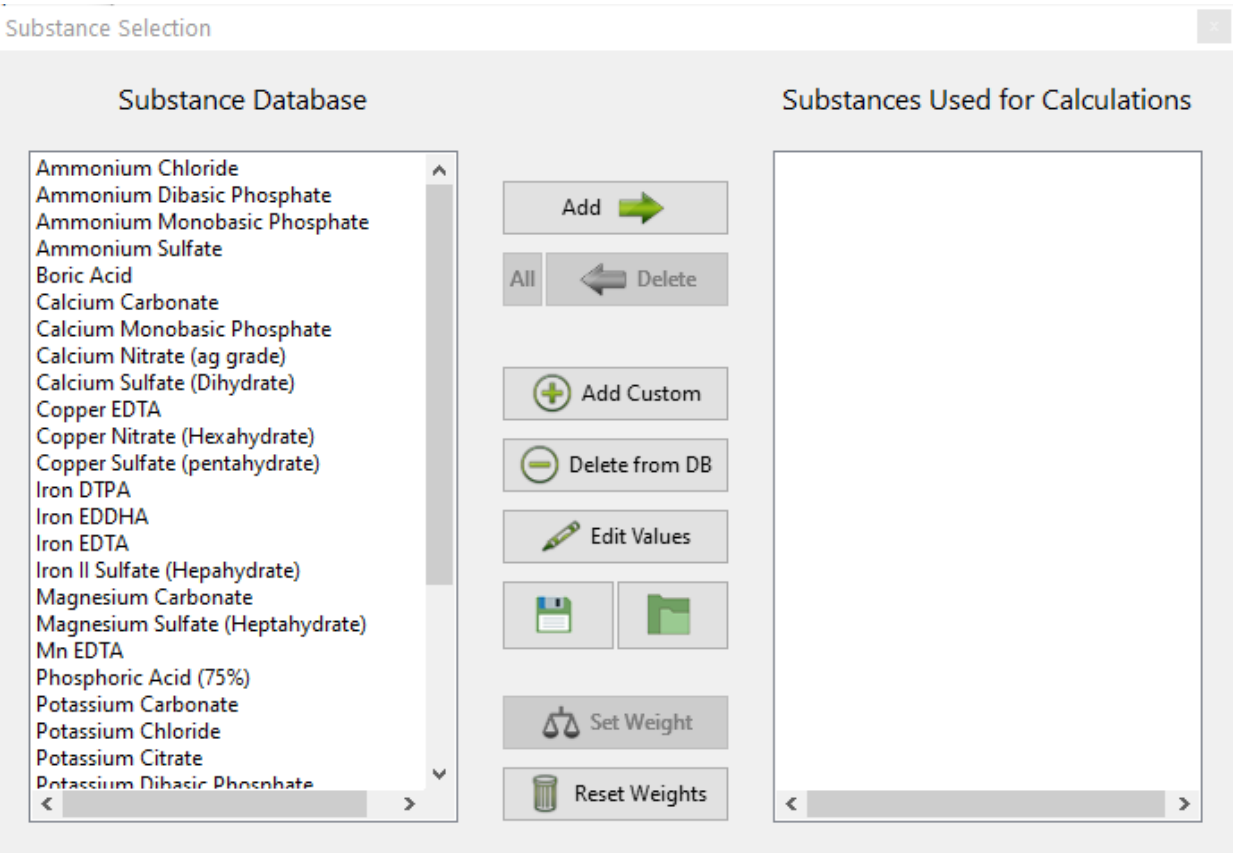
keep the nutrient solution as sterile as possible. Carbon filters are also very useful as they remove plant exudates that can contaminate the solution and cause problems within the crop itself. Many of these exudates are food for microorganisms, others are plant hormones that might cause unwanted responses in the plants. However both carbon filtration and UV filters can cause some issues – such as the destruction and adsorption of heavy metal chelates – so it is important to use chelates that are more resistant to UV and have less affinity for carbon filters to alleviate these problems.

There is certainly a lot more to the management of recirculating hydroponic solution than what I have detailed above, *it is important to note that some of these tips are simplifications and much better tailor-made solutions are possible with a proper analysis of each situation*. These are just some simple tips to hopefully make your change towards the use of recirculating systems a lot easier and should greatly increase your chances of success in the world of recirculating hydroponic setups.

About the default fertilizer database in HydroBuddy

Hydrobuddy is an open source calculator that seeks to help growers create their own hydroponic nutrient solutions. In order to do this, the program includes a database with a list of curated fertilizers that should be a good starting point for those interested in making their own nutrients. However, why these salts are included might not be clear to most growers, so I wanted to create a blog post to explain my

reasoning behind this particular repository and the purpose each one of these different salts might serve. It is also worth noting that the default list of nutrients is not by any means definitive – for example no silicon containing substances are included – so users are welcome to add their own substances using the "Add Custom" option and entering the composition of the fertilizer they want to add.



The HydroBuddy "Substance Selection" screen (v1.8) showing some of the nutrients in the default database

The idea of the database that comes with HydroBuddy is to allow you to create several types of nutritional tools, using different types of approaches. The table below shows you what each one of the substances contributes in terms of nutrition, as well as its qualitative effect on the pH of the solution and what its most popular use is. While some of these substances – such as Potassium Sulfate – are mainly intended to be used as part of the main nutrient solution, others such as Potassium Carbonate, are not intended to be used in this manner but they are intended to be used as buffering agents when doing pH adjustments or creating concentrated pH up/down

buffering solutions. There are also substances like – like Ammonium Chloride – that are not intended to be used for either of these purposes but mainly for supplementing a nutritional component, in this particular case, N as ammonium.

The main nutritional use of substances is also dependent on what the end-user has in mind. For example when a user wants to create a concentrated stock solution, substances such as Calcium Sulfate or Zinc Sulfate might not be very useful – due to their limited solubility or stability – while for users who want to create final solutions by direct addition of salts, these substances might be the best potential choice. Several different substances are provided for some nutrients to allow for this type of flexibility.

Another important factor can be cost, sometimes this is a more important factor than other considerations, such as which nutrient is the absolute best from a botanical perspective. This is part of the reason why – for example – 4 different forms of iron are present within the default database, this way users can see how much iron they would require from different sources and – depending on their particular application and cost range – make a decision about which iron source might be optimal. This also allows a user to consider using a cheaper source of iron – like Iron II Sulfate Heptahydrate – and then preparing their own chelates using a chelating agent, such as disodium EDTA.

Name	N1	N2	P	K	Mg	Ca	S	Fe	Mn	B	Zn	Cu	Mo	Cl	Na	Use	pH effect
Ammonium Chloride	■													■		S	↓
Ammonium Dibasic Phosphate	■		■													MN	↑
Ammonium Monobasic Phosphate	■		■													MN	↓↓
Ammonium Sulfate	■						■									MN	↓
Boric Acid										■						MN	↓
Calcium Carbonate						■										B	↑↑
Calcium Sulfate (Dihydrate)						■	■									MN	
Calcium Nitrate (ag grade)		■				■										MN	↓
Copper EDTA												■			■	MN	
Copper Nitrate		■										■				MN	
Copper sulfate							■					■				MN	
Iron DTPA								■							■	MN	
Iron EDDHA								■							■	MN	
Iron EDTA								■							■	MN	
Iron II sulfate (heptahydrate)							■	■								MN	
Magnesium Carbonate					■											B	↑↑
Magnesium Sulfate (heptahydrate)					■		■									MN	
Mn EDTA									■						■	MN	
Phosphoric Acid (75%)			■													B	↓↓↓
Potassium Carbonate				■												B	↑↑
Potassium Chloride				■										■		S	
Potassium Citrate				■												B	↑↑
Potassium Dibasic Phosphate			■	■												MN	↑
Potassium Monobasic Phosphate			■	■												MN	↓↓
Potassium Nitrate		■		■												MN	
Potassium Sulfate				■			■									MN	
Sodium Borate										■					■	MN	
Sodium Molybdate													■		■	MN	
Sodium Nitrate		■													■	S	
Zinc Nitrate (Hexahydrate)		■									■					MN	
Zinc Sulfate (Monohydrate)							■				■					MN	
Zn EDTA											■				■	MN	

This table shows all the salts included in the default HydroBuddy database (v1.8). N1 is N as Ammonium, N2 is N as nitrate. MN = Main nutrition, B = Buffering, S = Supplementation

For those with experience in hydroponic nutrient solutions it will be clear that many commonly used substances are missing – such as Magnesium Nitrate, Potassium Silicate, Nitric acid, Sulfuric acid, etc – these were present in previous versions of the software, but the abundance of choices was confusing to newer users, especially when they couldn't easily get their hands on many of these fertilizers from a practical perspective. Some nutrients, like urea, were specifically removed because of the larger potential to cause more harm

than good when used in hydroponics.The modifications to the database seek to solve these issues by providing a more condensed, yet very flexible list, that users can more effectively leverage to create their own solutions. *However, remember that you can add any substance you want by using the "Add Custom" button in the substance selection screen.*

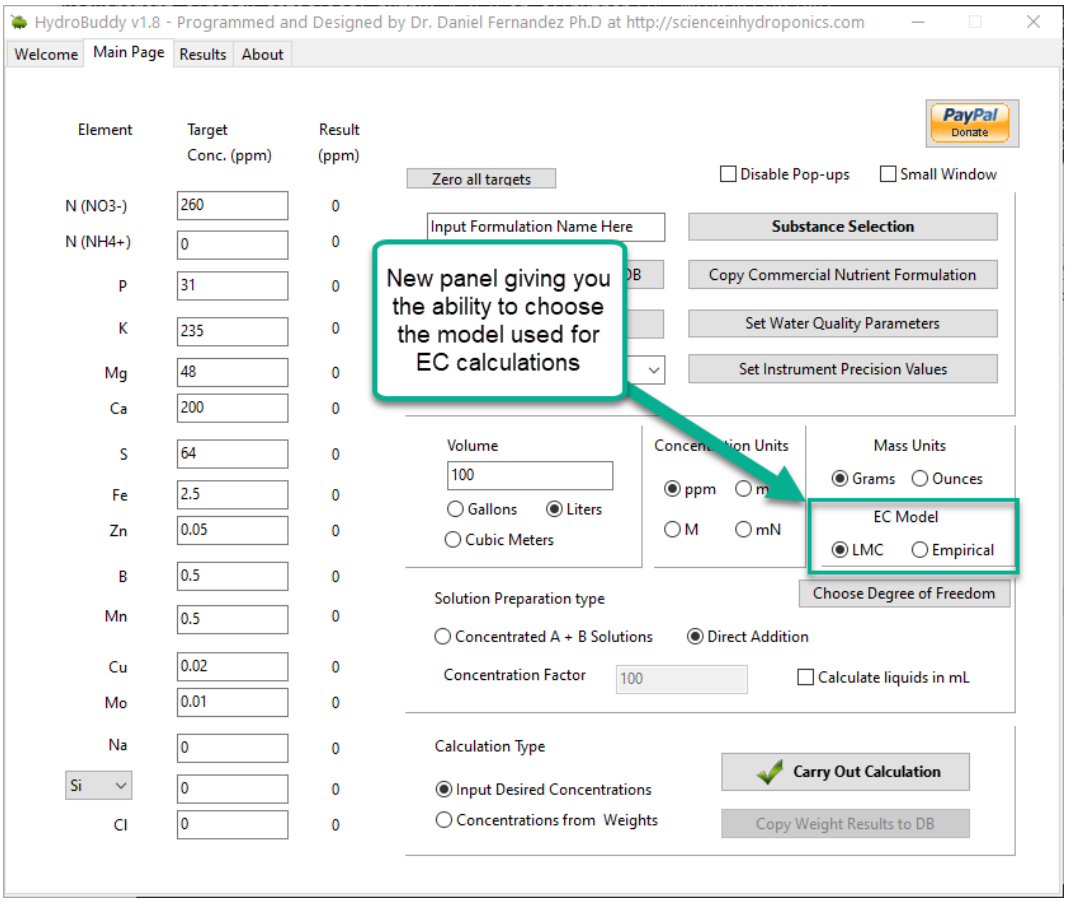
As you can see many considerations go into creating nutrient solutions and this database is a very generic attempt to provide you with the best tools to get you started in this world. However, if you find this task difficult or you would simply like to have additional help and guidance, feel free to book an hour of consultation time by using the booking function on the website or contacting me directly through the contact page.

A new conductivity model in HydroBuddy

On my previous post you can read about how I ran experiments to develop a conductivity model using empirical data in order to improve our ability to predict EC values from the concentration of individual nutrients in a hydroponic nutrient solution. In this post I will now talk about how this was finally implemented in HydroBuddy, what form it took and what kind of result can be expected from it. The implementation discussed in this post has already been updated to the HydroBuddy github along with all the experimental data used to derive this empirical EC model.

Given the amount of data and the nature of the problem at hand, the easiest and most accurate way to build a model was

to use a simple linear regression algorithm. As previously shown this model was able to give great results within the data, even when performing random training and testing splits. I have added a jupyter notebook to the github repository, along with all the data we measured in order to allow you to see how all the calculations were done, how the model was created and the sort of accuracy the model got within the set of experimental results. You can also play with this notebook to develop your own models or analyse the data any further if you wish. You can also try to reproduce our experiments and help verify our results. The linear model was translated into FreePascal and added to HydroBuddy although the program still retains the ability to estimate conductivity using the previously available LMC based model.



New hydrobuddy implementation now including the ability to choose between LMC and empirical EC models.

The fact that we were able to create a model to accurately determine conductivity within this experimental space does not mean that this model will work to magically determine the

conductivity of any hydroponic formulation. These experiments were designed using five salts – calcium ammonium nitrate, ammonium sulfate, potassium sulfate, magnesium sulfate and monopotassium phosphate – which means that although our model is able to greatly describe conductivity in this space, the model is likely to run into trouble when attempting to describe a space that deviates too strongly from the one described above. This will be most evident whenever there are some cations or anions that are not present at all within these experiments. For example when silicates, chlorides or other such salts are used or when strong acids or bases are added to the solution.

Another important issue is the way these ions are paired. In our experimental process the concentration of Ca and N as nitrate always increased at the same time, meaning that the linear model implicitly carries this assumption. A setup were magnesium nitrate or potassium nitrate are used as well, will contain deviations from the current model that it is likely not very well prepared to deal with. A similar problem might happen when salts such as ammonium monobasic phosphate are used, since our model only contained a single example of a phosphate salt (monopotassium phosphate). While it is not easy to predict how much accuracy will be lost in these cases, we do expect the model to be significantly more inaccurate as other salts are used.

Additionally, our experimental setup did not contain any corrections of pH values, so the conductivity values described include a pH drift related with the amount of acid contributed by the potassium monobasic phosphate, which was not neutralized by a base. This will also cause differences with conductivity, if the conductivity is measured after the pH of the solution is corrected to the proper range used within the hydroponic process. Although at the concentration values used in hydroponics this should not be a big issue, it is still something worth considering.

As I mentioned above, the model is already implemented within the github repository – if you want to compile the program yourself – but the binaries won't be updated to v1.8 until later this week. I look forward to your feedback about the model and hope it can help – at least some of you – to dramatically improve the estimations of conductivity of your hydroponic nutrient solutions.