

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 its 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.

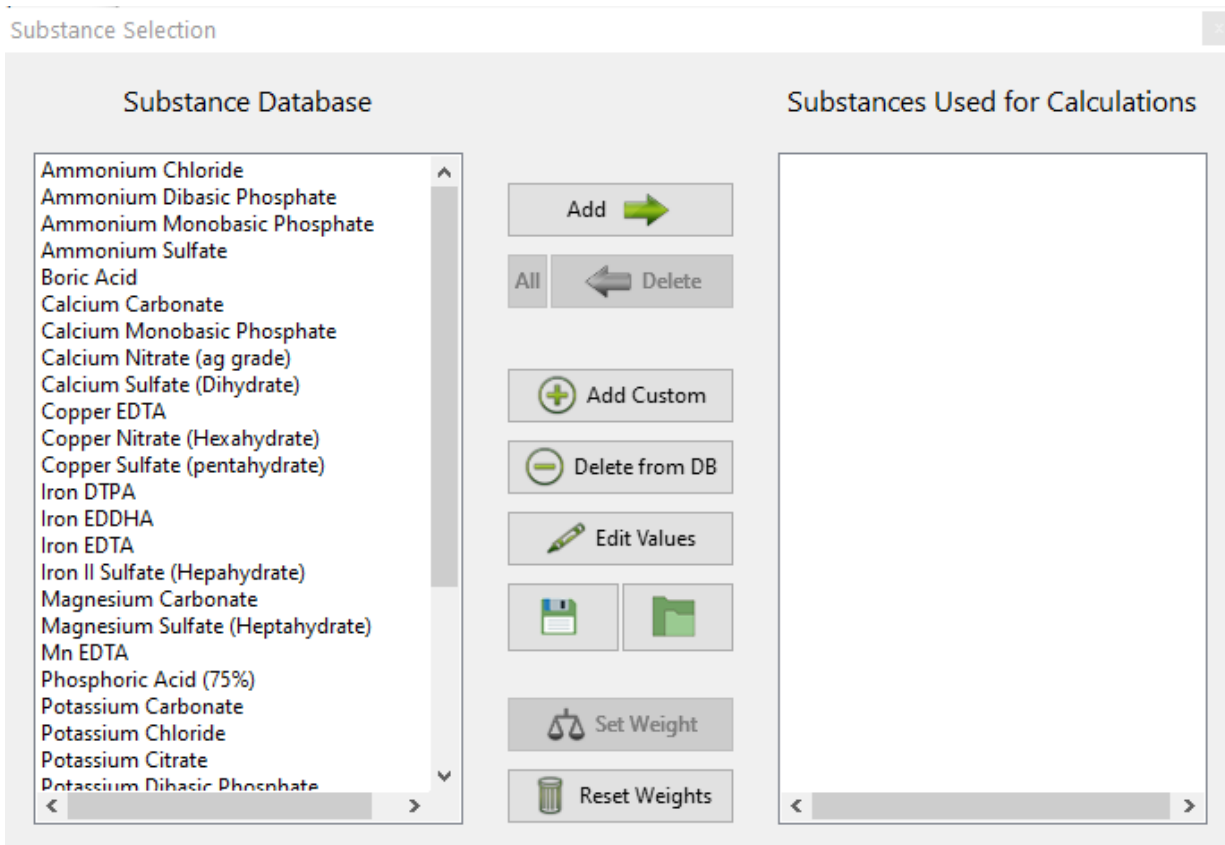
Add in-line UV filters and carbon filters. It is fundamental to ensure no microorganisms contaminate your nutrient solution. For this reason, online UV-filters are necessary to keep the nutrient solution as sterile as possible. Carbon filters are also very useful as they remove plant exudates that can 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.*

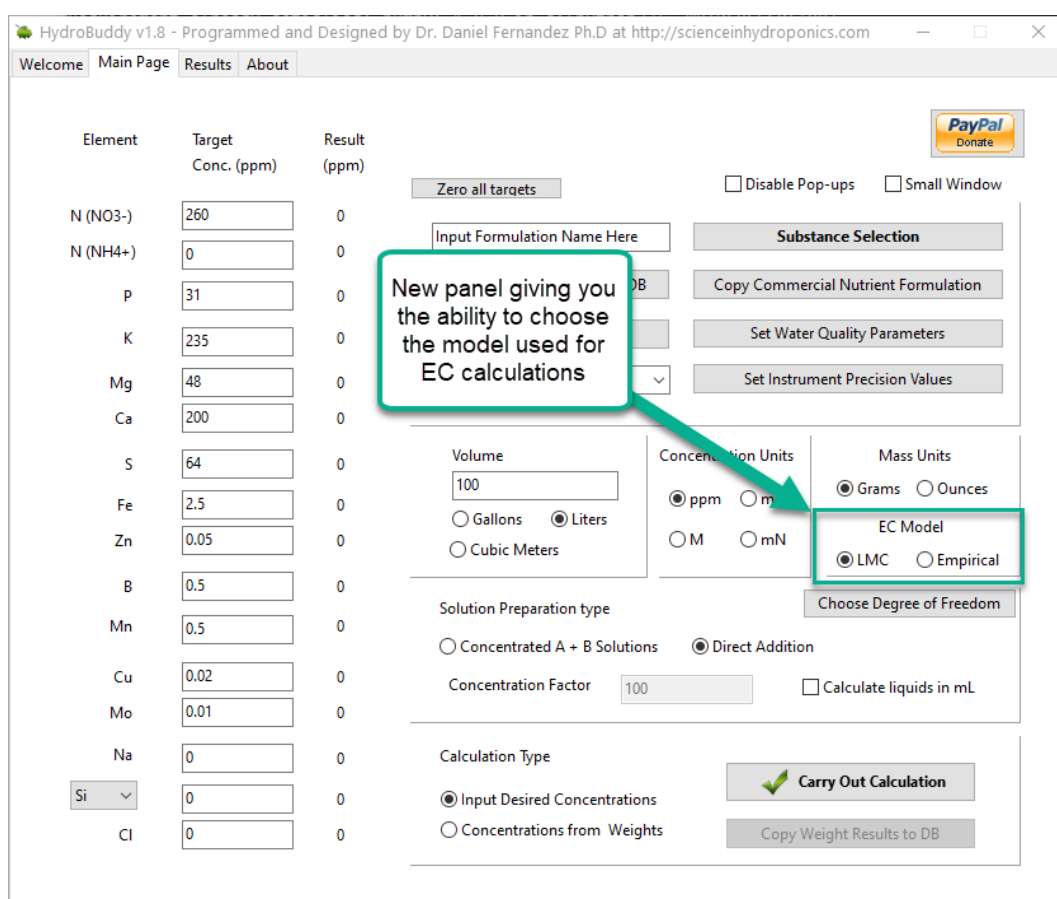
As you can see many considerations go into creating nutrient solutions and this database is a very generic attempt to provide you with the best tools to get you started in this world. However, if you find this task difficult or you would simply like to have additional help and guidance, feel free to 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.

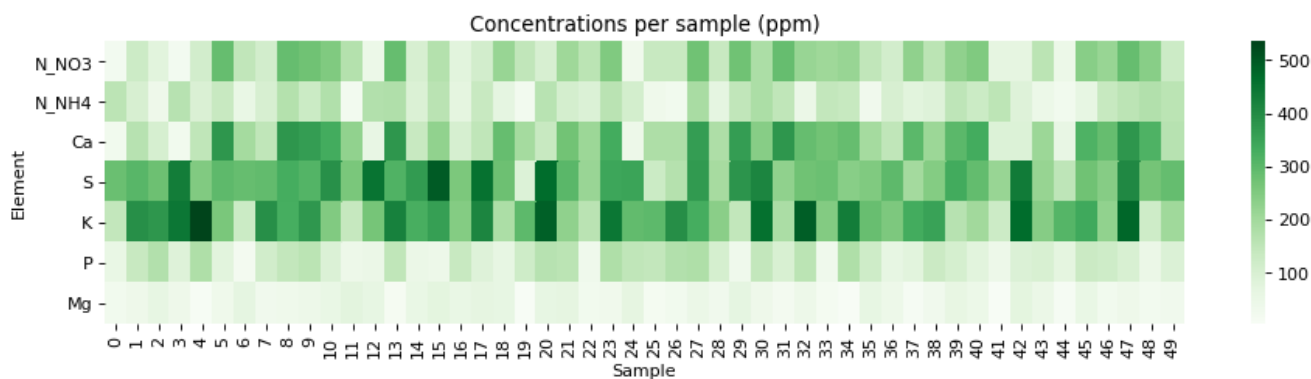
Another important issue is the way these ions are paired. In our experimental process the concentration of Ca and N as nitrate always increased at the same time, meaning that the linear model implicitly carries this assumption. A setup where magnesium nitrate or potassium nitrate are used as well, will 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.

Building a model to predict EC in hydroponic nutrient solutions

Electrical conductivity (EC) is one of the most useful parameters in the practical preparation of hydroponic nutrient solutions. This is because knowing the expected conductivity of a nutrient solution can allow you to prepare solutions without having to measure the total volume exactly, a parameter that is often hard to accurately determine in practice. Although determining the target conductivity is easy to do using small preparation volumes – which can be done accurately – it is often impractical to do so routinely, which is necessary if the actual composition of the nutrient solution is being changed as a function of time. Due to all the above, it is important to come up with accurate models to estimate the EC of nutrient solutions with only information about their mineral composition, without having to measure the value experimentally. In this post I am going to talk about how I created a model to do exactly this, taking advantage of multi-variable experimentation and simple modeling techniques.

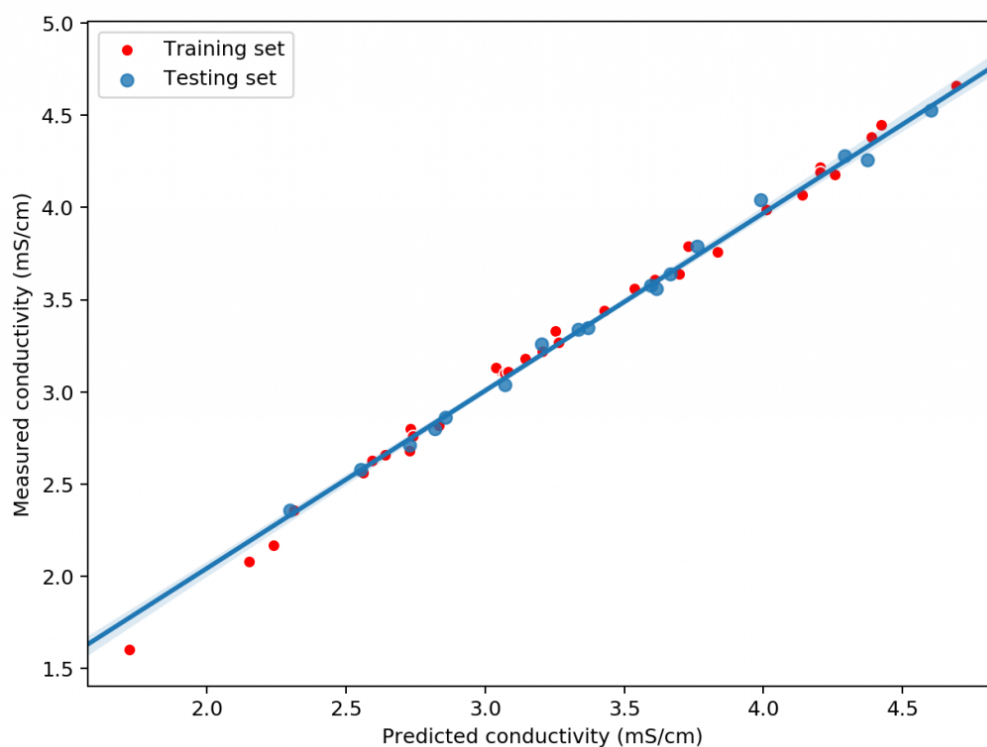


Mineral nutrient concentrations (ppm) of all the samples measured

The problem with conductivity modeling is that not all salts contribute the same to the conductivity of a nutrient solution. For example potassium sulfate can contribute significantly more to conductivity per gram compared to a salt like monopotassium phosphate. Furthermore, the addition of some salts can affect the conductivity of others (see my previous post on conductivity modeling in Hydrobuddy for more details). In the regime we use in hydroponics, the determination of electrical conductivity using data from limiting molar conductivity can lead to very skewed results, which makes these estimations of little usage in practice.

To solve this issue, I designed an experiment where 50 different EC measurements were made for different hydroponic nutrient solutions within the range of concentrations of nutrients that are reasonably expected in hydroponic culture, with some values being above these in order to ensure that all values encountered in practice will be within the measured ranges. The image above shows you all the concentrations that were measured within the experiment. To prepare the solutions I used calcium ammonium nitrate, potassium sulfate, magnesium sulfate heptahydrate, monopotassium phosphate and ammonium sulfate. All of these were agricultural grade salts in order to reflect the same impurities expected in a normal hydroponic setup. Note that no heavy metal salts were used since their contribution to the EC of a hydroponic nutrient solution is negligible.

Concentrated solutions of all the salts were prepared in 250mL volumetric flasks using a $\pm 0.001\text{g}$ scale and aliquots of these solutions were drawn using 5mL plastic syringes ($\pm 5\%$) in order to prepare final 250mL solutions using volumetric flasks. Conductivity measurements were done using an Apera EC60 conductivity meter that was previously calibrated using a 2 point calibration method. All the solutions were prepared using distilled water. The target concentrations for the solutions were determined using a pseudo random number generator in order to try to ensure a random distribution of samples within the concentration space of interest.

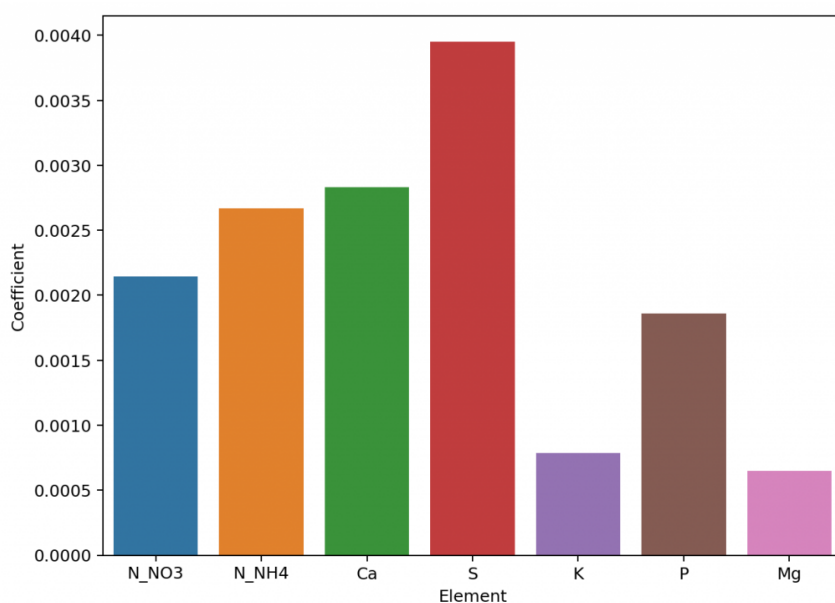


A sample modeling results for a random split with training (33 data points) and testing sets (17 data points)

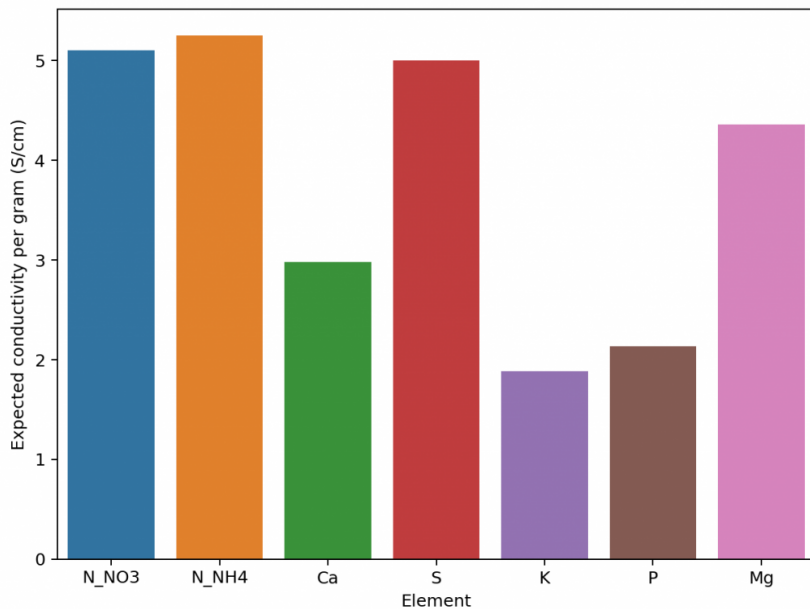
Using this data we constructed a linear model to attempt to predict conductivity. In order to evaluate the model we randomly split the results to get 33 data points used for model construction and 17 points left for model validation. Performing this process 100 times shows that the mean R^2 of the model on the training set is 0.995 while the average on the testing set is 0.994. This shows that the model is able to properly generalize the conductivity data in order to

properly predict the conductivity of the solution across the space studied. **The mean absolute error in the testing set was 0.036 mS/cm. This shows the high certainty with which we can make conductivity predictions.**

Exploring the model coefficients can also show us how different the contributions of the different elements to the conductivity of the nutrient solution can actually be. These results are surprising if you compare them to the conductivity contributions per gram that are expected from the limiting molar conductivity values, which are the conductivity values the ions exhibit on their own under very high dilutions (this is also the method used in HydroBuddy <=v1.65). We can clearly see here that in reality we are getting way more conductivity out of sulfate compared to the other elements and significantly less from magnesium. This means that at the makeup and concentration values used in hydroponics the Mg ions are not being able to contribute as much as they can when they are alone because their activity is being lowered by the other ions in solution, while the opposite case applies to sulfate.



Linear model coefficients for the different elements (proxy for their contribution to conductivity)



Expected conductivity values per gram using data from limiting molar conductivity values (taken from [here](#))

The above shows us why conductivity in hydroponics is so complicated, it shows how ions do not contribute equally to conductivity and how they behave very differently in real hydroponic solutions. Thankfully the above also shows how we can create a model using experimental data that is actually able to predict conductivity, since the relationships – although different than expected – are still highly predictable when enough experimental data is available. All the above experimentation took 4 hours to do – with the help of my lovely wife, who is also a chemist – and should allow me to add a very powerful model to predict hydroponic nutrient solution EC values to HydroBuddy.

All the above experimentation data will be open source and available in a github repository soon. We also hope to show you how all of this was done in a youtube video in the near future.

Monitoring the quality of fertilizer stock solutions

Hydroponic concentrated nutrient fertilizer manufacturers are not held to any routine quality standards by regulatory authorities in most countries. Although fertilizers need to be properly registered and their intended minimum compositions are shared with the public, the manufacturer never guarantees that each batch of the product will comply with any sort of quality standard and it's therefore possible for hydroponic nutrients to come out of a factory with compositions that significantly deviate between batches. People who make their own fertilizers are also not free from problems either, as issues further down the chain – with the fertilizer raw inputs – or issues related with human error, can and will still happen.

Because of these problems, a very important part of every hydroponic grower's process should be to establish some quality guidelines to evaluate whether a given batch of nutrients – either bought or self-made – complies with what is expected and can therefore be used in the hydroponic crop. In today's post I will talk about the properties that you can measure in order to ensure that the quality of your inputs is sustained through time and how these measurements should be done.



These are two measurements that should always be done whenever you receive or prepare a new batch of hydroponic nutrient stock solution:

Density of the stock solution: The density of a hydroponic stock solution should always be measured and recorded. The density needs to be measured accurately, using a pycnometer and an accurate enough balance (+/- 0.01g). A 5 or 10mL pycnometer would be recommended and the balance should be able to measure up to at least 50g, to ensure that the measurement of the final weight of the pycnometer will be in range. You should first weight the empty and dry pycnometer, then fill it with liquid to the brim, place the stopper – some liquid will spill, this is how it's intended to work – then wipe any spilled liquid and weight the full pycnometer. The difference in weight divided by the pycnometer volume will give you the density. Make sure you also record the ambient temperature when the measurement is made.

pH of the stock solution: You can use a pH meter to determine the pH of a sample of the stock solution. You can use the regular pH tester you use to measure the pH of your hydroponic nutrient solutions, however make sure the pH meter does not remain for too long in the stock solution – more than what's

necessary to make the measurement – and wash it with distilled water and store it in pH meter storage solution as soon as the measurement is done. Also make sure the pH meter is calibrated right before making this measurement.

If any compounds are added incorrectly or the composition of the raw inputs was in anyway wrong, the above two parameters – pH and density – will tend to change, as they depend very strongly on the composition of inputs being the same. Of course, there are mistakes that can go undetected in these two domains but a stock solution that always records the same across batches will tend to be the same chemically. Every time you receive or prepare new solution record the above and ensure you never use any solution that deviates more than -/+ 5% from the median you have on your record. The deviation of the above two parameters also serves as a way to control how reproducible the manufacturing process of the stock solution actually is.

If there is a strong mismatch in these measurements when compared with the median of all past values, then you need to continue to actual chemical analysis of the nutrients to figure out what's wrong.

If you prepared the fertilizer yourself then it becomes important to check notes – always keep records of weights that are added when preparing solutions – and see if there were any changes in the chemical suppliers of any of the used inputs. Sometimes the quality and composition of certain chemicals can change dramatically between suppliers, so making changes from one to another can often require chemical analysis to ensure that the composition stays the same. A good example can be potassium silicate, where the exact grade and potassium to silicon ratio of the raw material can change a lot depending on the exact fabrication process used by the company making it.

Another important point is the accuracy of the instruments

used for the preparation of solutions. Sometimes the problem is that a scale or a volume measuring device lost calibration and generated errors in a previously unseen range. This can be particularly problematic if different instruments are used to measure different inputs, which can make some inputs subject to bigger errors than others and can therefore change the ratio between different nutrients in the hydroponic solution.

Using calcium sulfate in hydroponics

Calcium is a very important element in plant nutrition and can be supplied to plants through a wide variety of different salts. However, only a handful of these resources are significantly water soluble, usually narrowing the choice of calcium to either calcium nitrate, calcium chloride or more elaborate sources, such as calcium EDTA. Today I am going to talk about a less commonly used resource in hydroponics – calcium sulfate – which can fill a very important gap in calcium supplementation in hydroponic crops, particularly when Ca nutrition wants to be addressed as independently as possible and the addition of substances that interact heavily with plants wants to be avoided.



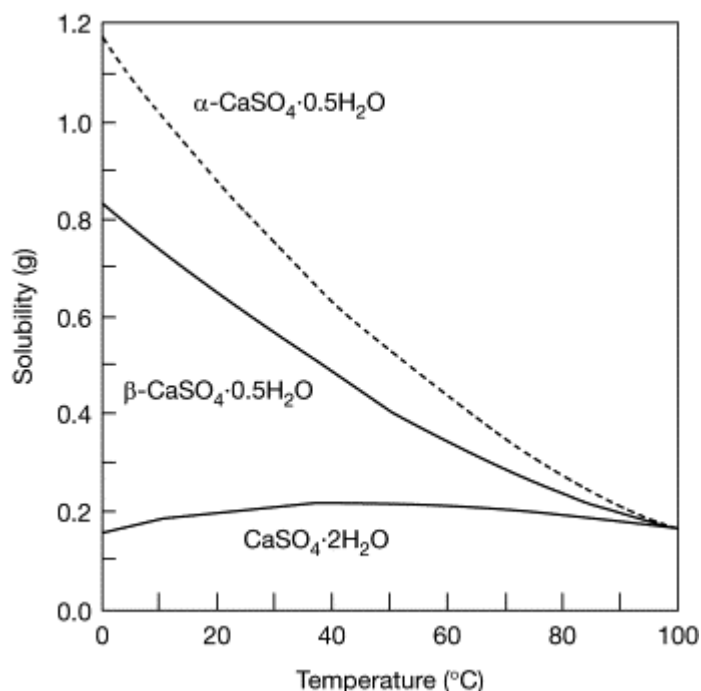
Calcium sulfate dihydrate (gypsum)

There are some important reasons why you don't hear too much about calcium sulfate in hydroponics. Some websites actually recommend heavily against using this substance in hydroponic nutrient solutions. Why is this the case? The core issue is calcium sulfate's solubility, with this substance traditionally considered "insoluble" in chemistry. However all

substances are soluble to one or another degree – even if to an extremely small degree – but calcium sulfate is actually at the very border of what is considered a soluble substance in regular aqueous chemistry.

At 20C (68F), calcium sulfate dihydrate – the form most commonly available – has a solubility of around 2.4 g/L. In practice this means that you can have up to around 550 ppm of Ca in solution from calcium sulfate dihydrate before you observe any precipitation happening. This is way more than the normal 150-250 ppm of Ca that are used in final hydroponic nutrient solutions that are fed to plants. You could supply the entire plant requirement for calcium using calcium sulfate without ever observing any precipitate in solution. *At the normal temperature range that hydroponic nutrient solutions are kept, the solubility of calcium sulfate is just not an issue.* To add 10 ppm of Ca from calcium sulfate you need to add around 0.043g/L (0.163g/gal). You should however avoid using calcium sulfate for the preparation of solutions for foliar sprays as it will tend to form precipitates when the foliar spray dries on leaves, the leaves will then be covered with a thin film of gypsum, which is counterproductive.

Calcium sulfate has a great advantage over other ways to supplement calcium in that the anion in the salt – sulfate – does not contribute as significantly to plant nutrition. Other sources, such as calcium chloride or calcium nitrate, will add counter ions that will heavily interact with the plant in other ways, which might sometimes be an undesirable effect if all we want to address is the concentration of calcium ions. Other sources such as Ca EDTA might even add other cations – such as sodium – which we would generally want to avoid. Calcium sulfate will also have a negligible effect in the pH of the solution, unlike other substances – like calcium carbonate – which will have a significant effect in the pH of the solution.



Solubility (g per 100mL) of calcium sulfate as a function of temperature for different crystalline forms (see more [here](#))

A key consideration with calcium sulfate is also that its dissolution kinetics are slow. It takes a significant amount of time for a given amount of calcium sulfate to dissolve in water, even if the thermodynamics favor the dissolution of the salt at the temperature your water is at. For this reason it is very important to only use calcium sulfate sources that are extremely fine and are graded for irrigation. This is sometimes known as ["solution grade" gypsum](#). I advice you get a small amount of the gypsum source you want to use and test how long it takes to dissolve 0.05g in one liter of water. This will give you an idea of how long you will need to wait to dissolve the calcium sulfate at the intended temperature. Constant agitation helps with this process.

An important caveat with calcium sulfate is that its relatively low solubility compared with other fertilizers means that it cannot be used to prepare concentrated nutrient solutions. This means that you will not be able to prepare a calcium sulfate stock solution or use calcium sulfate in the preparation of A and B solutions. As a matter of fact the formation of calcium sulfate is one of the main reasons why concentrated nutrient solutions usually come in two or more

parts, to keep calcium and sulfate ions apart while they are in concentrated form. *Calcium sulfate should only be added to the final nutrient solution and adequate considerations about temperature and dissolution time need to be taken into account.*

Can you use regular soil fertilizers in hydroponics?

If you have just started your journey into hydroponics you're probably wondering why you need to spend your money in hydroponic specific nutrients when there are so many cheaply available soil fertilizers sold out there. Certainly there are all plant food and there must be some way you can use all these cheap soil fertilizers to create a suitable replacement to feed your hydroponic crop. In this post I want to explain some of the key differences between hydroponic and soil fertilizers, when soil fertilizers can be used in hydroponics, how they can be used and when it is definitely a bad idea to try to use them.



Some slow release soil fertilizer being added to plants

To understand the difference between soil and hydroponic fertilizers we must first understand the difference between both growing setups. In hydroponics we try to grow plants in sterile and chemically neutral supporting media where all the nutrients are expected to be provided by the nutrient solution while in soil the media is not intended to be inert – it contains organic matter, minerals that can dissolve and living microbes – and we expect some of these to provide nutrition to our plants. Fertilizers for soil are intended to aid this process – provide material for microbes to process and supplement some of the lacking elements in the soil – while hydroponic fertilizers intend to provide all required nutrition in the forms that are mostly favorable for plants. Fertilizers for soil are often also meant to be applied once or very occasionally, while fertilizers for hydroponics are expected to be fed to the plant very frequently.

In chemistry terms, this means that fertilizers for soil will tend to contain forms of nitrogen that can be processed slowly by microbes in soil – urea and ammonium salts – while hydroponic fertilizers contain mostly nitrate salts. It is rare for soil fertilizers sold to home growers to contain large amounts of nitrates because these are easily washed away by rain, are strong pollutants of underwater ground sources and are only shortly available for plants due to their high mobility in soil. However ammonium and urea are a terrible idea in hydroponics since ammonium fed frequently strongly acidifies the media and plants supplied their nitrogen only from ammonium in solution will tend to show toxicity issues quickly. Soil fertilizers rely on bacteria to convert this ammonium and urea to nitrate in a slow process, hydroponic fertilizers do not, they contain nitrate which is the final form of nitrogen that plants prefer for healthy growth.

— GUARANTEED ANALYSIS — F1144

Total Nitrogen (N)	18%
1.62% Ammoniacal Nitrogen	
2.46% Nitrate Nitrogen	
13.89% Urea Nitrogen	
0.03% Other Water Soluble Nitrogen	
Available Phosphate (P ₂ O ₅)	18%
Soluble Potash (K ₂ O)	21%
Magnesium (Mg)	0.50%
0.50% Water Soluble Magnesium (Mg)	
Boron (B)	0.02%
Copper (Cu)	0.05%
0.05% Water Soluble Copper (Cu)	
Iron (Fe)	0.10%
0.10% Chelated Iron (Fe)	
Manganese (Mn)	0.05%
0.05% Chelated Manganese (Mn)	
Molybdenum (Mo)	0.0005%
Zinc (Zn)	0.05%
0.05% Water Soluble Zinc (Zn)	

Derived from Ammonium Sulfate, Potassium Nitrate, Urea, Soy Protein Hydrolysate, Monopotassium Phosphate, Sulfate of Potash, Magnesium Sulfate, Boric Acid, Copper Sulfate, Iron EDTA, Manganese EDTA, Sodium Molybdate, and Zinc Sulfate.

Information regarding the contents and levels of metals in this product is available on the Internet at <http://regulatory-info-sc.com>

Guaranteed Minimum Analysis

Total Nitrogen (N)	20%
Nitrate Nitrogen	12.1%
Ammoniacal Nitrogen	7.9%
Urea Nitrogen	0%
Available Phosphoric Acid (P₂O₅)	8%
Soluble Phosphorus	3.4%
Soluble Potash (K₂O)	20%
Soluble Potassium	16.6%
Calcium (Ca)	0%
Magnesium (Mg)	0.25%
Chelated Iron (actual) (Fe)	0.100%
Chelated Manganese (actual) (Mn)	0.050%
Chelated Zinc (actual) (Zn)	0.050%
Chelated Copper (actual) (Cu)	0.050%
Boron (actual) (B)	0.020%
Molybdenum (actual) (Mo)	0.015%
EDTA (chelating agent)	1.24%

Comparison between a couple of typical water soluble soil (left) and hydroponic (right) fertilizer labels.

The image above shows you a comparison between the labels for a water soluble soil and hydroponic fertilizer. In terms of NPK they both seem to be similar fertilizers, but the hydroponic fertilizer will have most of its nitrogen as nitrate while the other fertilizer has most of its nitrogen as urea. There are some other differences, mainly that the amount of phosphorous in the soil fertilizer is more than double that of the hydroponic fertilizer, which is also common given that phosphate is fixed rapidly in soil and therefore a higher excess is often added to ensure plants get enough supply. At an application of 1g/L the soil fertilizer would provide 75+ ppm of phosphorous while the hydroponic one would provide around 35. Also note that none of these two fertilizers would be enough to provide total plant nutrition since they both lack a source of Ca, which is commonly provided via a separate product in both cases.

So can any soil products be useful in hydroponics? Yes. First you need to completely avoid products that contain N mainly as urea or ammonium. Useful products to get for your hydroponic

grow will be fully water soluble and will either contain nitrogen solely as nitrate or no nitrogen at all. A very coarse DIY formula can usually be put together using something like a micro nutrient containing 0-10-10 bloom fertilizer (which contains no nitrogen) coupled with a source of nitrate, like agricultural grade calcium nitrate. You can use [Hydrobuddy](#) – my open source hydroponic nutrient calculator – to figure out the nutrient contributions of each one of the products you decide to get or have easily available and create an acceptable formulation from their use. The program also contains a long list of readily available raw salts that you can use to make your own fertilizer formulations from scratch if you wish to do so.

In the end, soil products for home growers are not designed for hydroponics use and should therefore be avoided except as a last resort if raw salts or hydroponic specific nutrients cannot be purchased. If you're interested in saving money, learning how to prepare your own fertilizers from raw salts will always be the best and cheapest option, provided you have the time and desire to learn how to do it properly.

Accurately preparing large quantities of concentrated hydroponic nutrients

When preparing concentrated solutions for hydroponics it is important to have a reproducible process that always generates the exact same results. If this is not done, you'll obtain different nutrient concentrations between different batches and the concentrated nutrient additions to create the final

nutrient solutions will yield inconsistent results. To address the potential variability of the concentrated solution manufacturing process we need to understand the different sources of error present and come up with ways to modify the process to generate more reproducible results. In this blog post I will talk about the largest source of error when preparing larger batches of concentrated nutrient solutions and how this error can be greatly reduced in order to obtain both more precise and accurate results.



Picture of a type A 250mL volumetric flask.

The process of preparing hydroponic concentrated solutions involves two steps. First, you dissolve raw fertilizer salts into some volume of distilled or RO water and then you take this volume of solution to a desired final volume of solution using the same source of water. In a small scale setup this process is very simple to carry out, since we can just weight and dissolve all our salts in some fraction of the desired final volume and then use a precise instrument to measure total volume – most typically a volumetric flask – to take our solution to the final desired volume. For example if we desire to prepare 250 mL of concentrated nutrient solution and we use

a well calibrated scale with $\pm 0.001\text{g}$ of precision and an A grade volumetric flask with a precision of $\pm 0.3\text{mL}$, the error we expect to get from a 500mg salt will be $\pm 4.77\text{ ppm}$ with a 99% confidence. Since the concentration of this salt in the concentrated solution is 2000 ppm, we get a final result of $2000 \pm 4.77\text{ ppm}$. If both instruments are calibrated this is a very precise and accurate result.

When we move to larger amounts of solution we usually get better on the side of mass. This is because we can still get scales that weight with $\pm 0.1\text{g}$ precision even at weights exceeding 50kg, so our error as a fraction of the total measurement remain in the 0.01% to 1% region pretty easily. However things get way worse in terms of volume. If you are preparing 100 gallons of nutrient solution – around 378 liters – you will be able to weight the salts precisely and accurately but when it comes to measuring final volumes of solution, you are not going to be very lucky. The volume marks in tanks are widely inaccurate and are not even standardized to any level of significant precision or accuracy plus accurately measuring whether water is at a given level in a tank is a very error prone process because of how wide the tank area is.

Although we don't usually have a way to adequately measure final volume, we do have a way to measure volume going into a tank in the form of flow meters, which can give us significant accuracy and precision. However, to be able to properly use the flow meter – know how much volume we need to actually get to the final volume we want – we must obtain information from a precise and accurate low scale process. To do this you can carry out the following steps:

- Get a precise and accurate scale (calibrated and at least $\pm 0.001\text{g}$ in precision)
- Get a scale that can weight up to 500g that can measure with at least $\pm 0.1\text{g}$ precision (if the one above does not).

- Get a 250 mL type A volumetric flask (should be around +/- 0.3 mL in precision).
- Get a 250mL beaker
- Get a plastic lab washing bottle and fill it with distilled water
- Calculate the salts you would need to dissolve to arrive at your desired concentrations at a 250mL final volume of concentrated solution
- Weight those salts and put them in a beaker, take note of all the exact weights added.
- Weight the dry, empty volumetric flask
- Add approximately half the volume of distilled water to the beaker and dissolve the salts
- Transfer to the volumetric flask, use the washing flask to fill the volumetric flask up to the calibration line (bottom of water meniscus is touching the line when viewed at eye level).
- Weight the flask with the solution
- Calculate the weight of water (weight of flask with solution – weight of flask – sum of weight of salts)

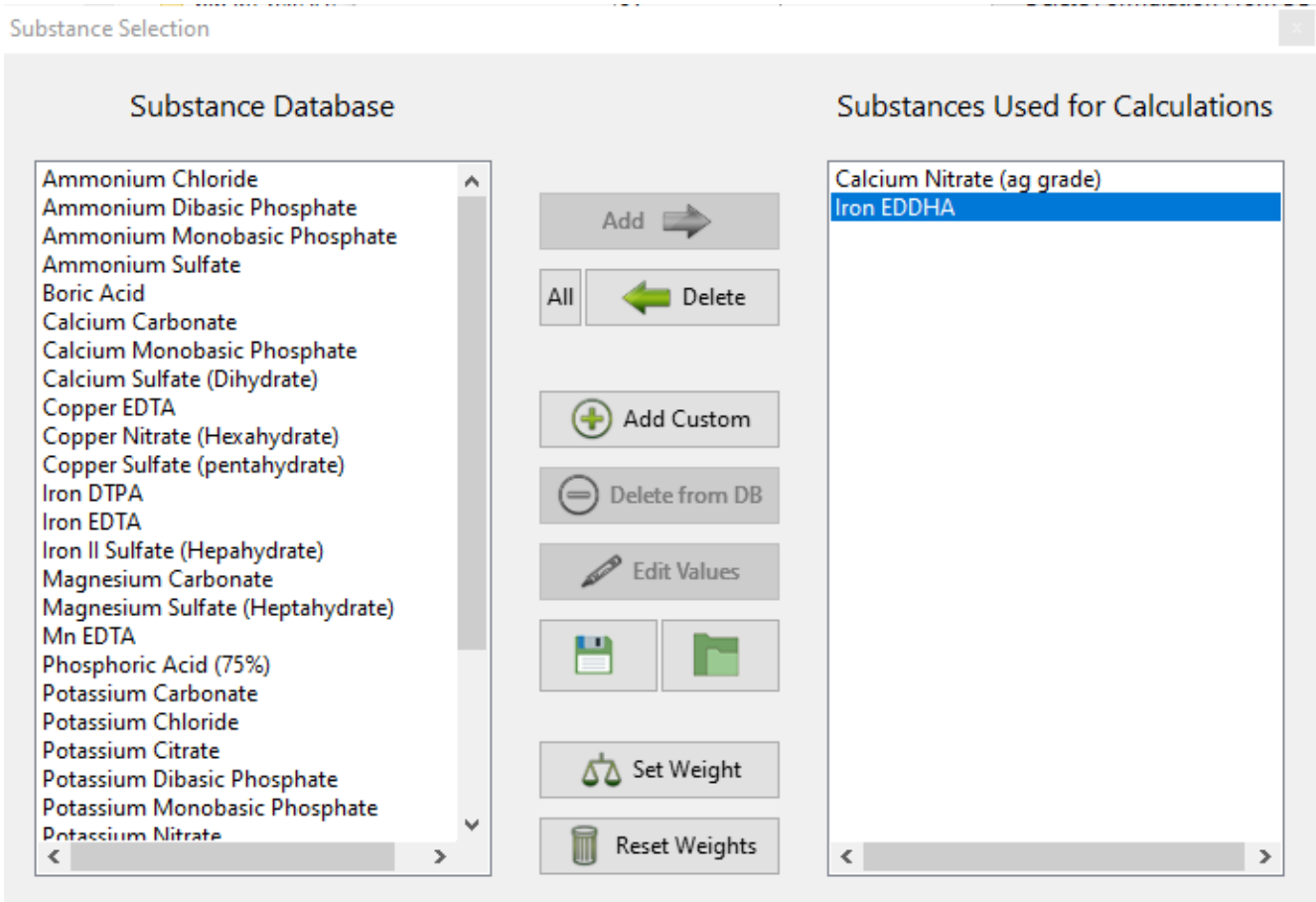
If the procedure above was carried out between 10-25C (50-77F) we can approximate the density of water to 1.0g/mL with little error (around 0.003g/mL). This means that we know the volume of water that was required to get to the desired final volume and we can then transfer this volume to our preparation procedure when we use a large tank. If the volume of water required for the preparation of the 250mL solution was just 230mL, then we can assume that the volume required to prepare 100 gallons will be 92 gallons, as the salts, when proportionately scaled, will take up the same volume and will require the same amount of water proportionately to reach the final desired volume.

When this type of procedure is done and an accurate and precise flowmeter is used, we can usually achieve concentration values at large scales that will be in the

0.1-1.0% error range, which is way better than anything that can be achieved by just using lines in tanks or procedures that use flow meters but ignore what the actual amount of water added needs to be in order to reach the desired concentration (many people achieve the salts take up no volume, which is a mistake). Having low errors in concentrated solutions means there will be less variability in final nutrient solution composition and therefore more reproducibility in crops.

HydroBuddy has now been updated to v1.70: New features and modifications

My free and open source hydroponic nutrient calculator has been available since 2010, going through many iterations and changes through the years. The latest version as of May-24-2020 is now 1.70, which you can download [here](#). This new release implements some important updates and modifications. In this post I will write about these, the reason why they have been made and the features that I am implementing for the next version of the software.



New substance selection screen in HydroBuddy v1.70

Most changes in this version have been done in the “Substance Selection” section of the program, which is accessible through the button of the same name in the “Main Page” tab. This is the “heart” of the program as this is where users decide what raw inputs they want to use and where they can manage the library of inputs that are actually available for calculations. In previous versions a very wide library of inputs was available by default, including many inputs that were rarely of any practical use in hydroponics and were there for illustrative purposes. A good example of this is a salt like “Calcium Nitrate (Tetrahydrate)” which is very rarely used by hydroponic growers as commercial “Calcium Nitrate” is actually a calcium ammonium nitrate salt that is very different in chemistry and composition to pure calcium nitrate tetrahydrate.

To solve the problem mentioned above I have completely rebuilt the substance database to include only commercially available raw fertilizers that make sense and are actually used in

common situations in hydroponics. This included adding a lot of different metal chelates and salts that were previously ignored but are now part of the HydroBuddy default database.

Another issue I wanted to address was the confusion some users have about where to buy these chemicals and potentially get some revenue to support the development of the software at no additional cost to the user. For this reason I have added manually selected links to all the raw fertilizers that are included with the DB so that users who want to buy small quantities of those can also support the software when they do so.

The screenshot shows the HydroBuddy v1.7 software interface. The title bar reads "HydroBuddy v1.7 - Programmed and Designed by Dr. Daniel Fernandez Ph.D at http://scienceinhydroponics.com". The main window has tabs for "Welcome", "Main Page", "Results", and "About". The "Results" tab is active, displaying a table of substances and a nutrient analysis table.

Substance Name [click for url]	Formula	Mass (g) [Edit to fine-tune]	Preparation Cost
Calcium Nitrate (ag grade)	5Ca(NO3)2.NH4NO3.10H2O	141.378	1.1
Ammonium Monobasic Phosphate	(NH4)H2PO4	0	0
Potassium Monobasic Phosphate	KH2PO4	63.758	2.8

A green arrow points from a text box to the "Ammonium Monobasic Phosphate" row in the table. The text box contains the following text:

Clicking leads to amazon affiliate links that support the software at no additional cost to the user

Element	Result (ppm)	Concentration (%)	Deviation
N (NO3-)	203.584	1.8%	+/- 0.1%
K	183.189	-8.4%	+/- 0.1%
P	145.1	383.7%	+/- 0.6%
Mg	0	0%	+/- 0%
Ca	268.618	0%	+/- 0%
S	0	0%	+/- 0%
Fe	0	0%	+/- 0%
Zn	0	0%	+/- 0%
B	0	0%	+/- 0%
Cu	0	0%	+/- 0%
Mo	0	0%	+/- 0%
Na	0	0%	+/- 0%
Si	0	0%	+/- 0%
Cl	0	0%	+/- 0%
Mn	0	0%	+/- 0%
N (NH4+)	15.552	-22.2%	+/- 0.1%

Values calculated for the preparation of 100 liters

Predicted EC Value: EC=1.6 mS/cm

Buttons: Stock Solution Analysis, Nutrient Ratio Analysis, Detailed Per Substance Contribution Analysis

Export To Csv button

HydroBuddy v1.7 contains clickable substance names in the result tab that take you to amazon affiliate links that sell the products mentioned at no additional cost to the user.

The "Substances Used" tab has also been enhanced with a new

“Save/Load” functionality that enables users to save or load lists of substances used to avoid the hassle of having to go through and select substances whenever they want to prepare a certain solution. This has also been very annoying for me in the past as having to go through different sets of inputs used for different purposes can be a very time consuming exercise. With this new feature all I have to do is save one list for each one of my needs and a single click of the “Load” button can easily change a list of 5+ inputs without the need for any tedious and – mistake prone – manual changing. Another small manual enhancement has been the addition of a small “All” button next to the “Delete” button, which allows you to delete all the substances present in the “Substances Used for Calculations” list.

Another change in this version was a decision to go with a 32 bit compiler in Windows in order to ensure that the variables for this operating system are all 32 bit. This will enable users who are using both 32 and 64 bit operating systems to use the software without problems. This was an issue in the past as many users still use old 32 bit systems and they were having problems having to manually compile HydroBuddy in some of their old machines. Sadly I still do not own a Mac, so HydroBuddy has yet to be available as a download for MacOSX and the software will need to be individually compiled by all of those who wish to use it in their MacOSX setups.

One of the features that is lacking most now is an ability to import databases from previous versions, as each time the software is updated users haven't been able to take advantage from previous custom databases built using the software due to problems with compatibility across releases (new DB fields being added, edited, etc). For the next version of the software I am working on a DB importing feature that should eliminate this issue so that users can benefit from the latest HydroBuddy releases without having to tediously add all their old substances to the new release.

With all the above said, I hope you enjoy this new version of the software. If you have any suggestions or comments about the above please feel free to leave your comments in this post!