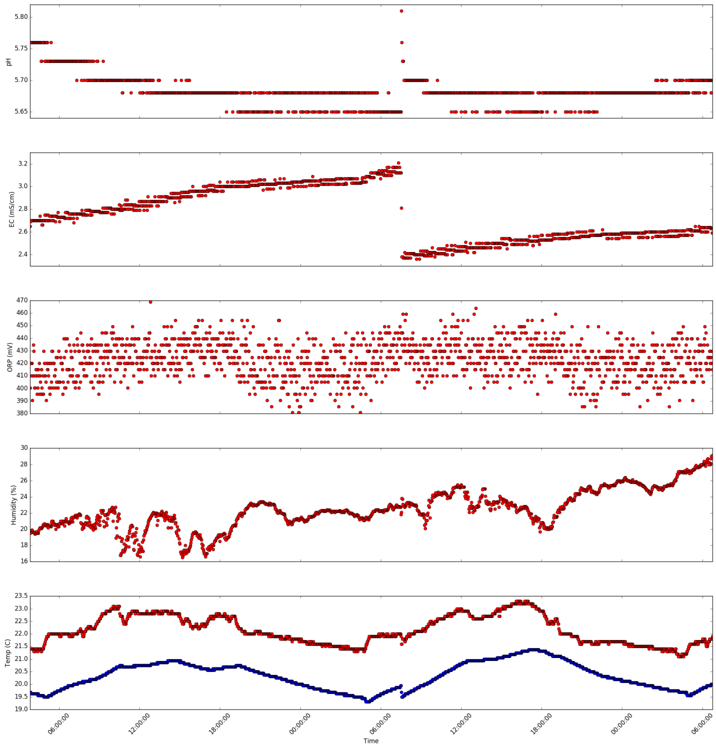
Automating a hydroponic system: Sensors and monitoring

Hydroponic systems benefit greatly from gathering more information as this gives the grower the ability to better diagnose problems and better understand the evolution of their hydroponic crops. Usually growers limit the information they gather to single sensor measurements carried out either at different points during the day or even only when nutrient solutions need to be changed. These measurements are often not recorded and are difficult to analyse in a wider context. Today I am going to talk about the automation of sensors in a hydroponic crop and the benefits this can yield you in the longer term. I will give you some advice regarding how to do this and will in a later post provide some practical steps to achieve an automatically monitored setup. Below you can see a picture of the output of my home hydroponic setup monitoring pH, EC, ORP, humidity, ambient and solution temperatures.

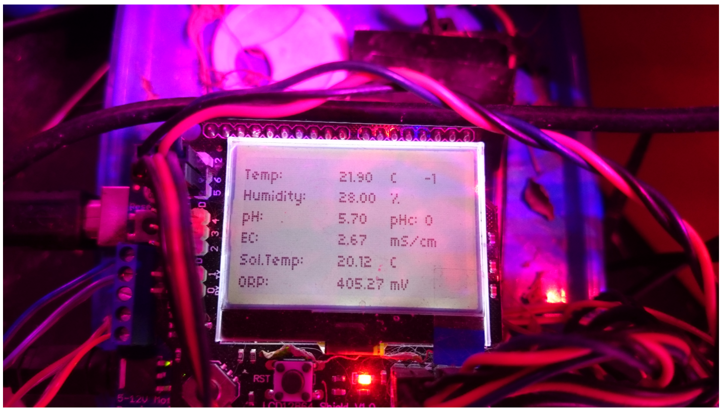


Automating sensors is not only having sensors that can take readings at predefined intervals but also making sure that the reading from these sensors are stored so that they can be used for analysis and diagnosis later on. Thankfully these days we have Arduino micro-controllers which are compatible with a wide variety of sensors that can be used for automated monitoring. We also have very cheap raspberry pi computers which we can use to store this information and build a database with our sensor information. Ideally we would like to monitor as many variables as possible but we are somewhat limited both by cost and the sensor capabilities of the Arduino micro-controllers. If you want to perform automated monitoring then you would definitely want to buy pH, EC, ambient temperature, solution temperature, humidity and carbon dioxide sensors. If you have more money or want to have more data then I would also advice getting a dissolved oxygen sensor and an ORP sensor. If you have a large grow room then you might want to place several CO2 and temperature sensors to properly monitor the entire crop. Here is a small shopping list with sensors and micro-controllers you could use for this:

- Temperature and humidity sensor 5.20 USD
- Arduino UNO 23.90 USD
- Raspberry Pi 39.95 USD
- ORP sensor 89.05 USD
- pH sensor 56.95
- EC sensor 69.90 USD
- Arduino LCD shield 24.95 USD
- Dissolved Oxygen 257.45 USD
- Real-time clock module 13.55 USD
- CO2 sensor 56 USD

Although the LCD shield isn't really necessary for the setup it does allow you to write an Arduino program that displays readings right away. This is very useful as you can see readings as they happen within your hydroponic crop. The image below shows you how this looks like within my home hydroponic setup. In this setup I have all the sensors constantly taking measurements from the crop, which are displayed in this LCD screen. There is also a raspberry pi connected to this Arduino that records one measurement every 2 minutes. I don't record measurements any faster since this would cause the memory usage to grow very fast within the Raspberry pi without any important gains in the amount of knowledge gained from the information taken.

—



—

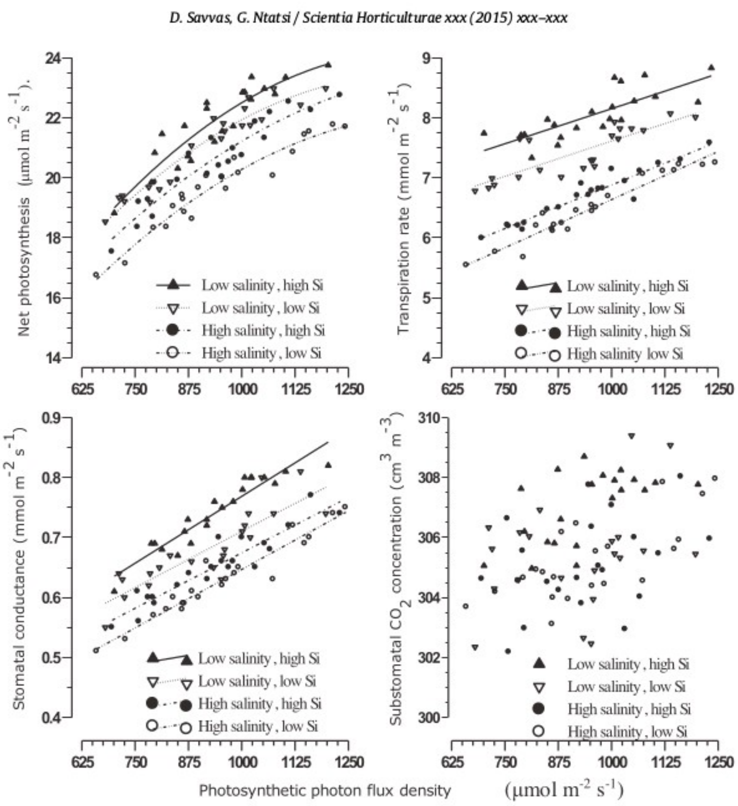
It is also important to know that the sensors should be industrial quality sensors designed to be kept submerged all the time. For example the above ORP, dissolved oxygen and EC meters are not designed for being constantly submerged so after a while they will stop working and you will need to change them. However if you clean the sensors around once a week and cover the body of the sensor – especially where the cable goes out the back – with electrical tape you can significantly extend their service life. After they run out you can still use the interface to connect an industrial grade sensor. It is worth noting that all sensors can lose their calibration so you want to calibrate your pH/EC sensors at least once every month within this setup. Also when taking sensor measurements you will want to take the median of a large number of measurements (>100) in order to ensure better stability.

Within a followup post I will share the code I use for my automated home setup as well as some additional information dealing with the automatic use of peristaltic pumps to automatically adjust pH/EC and ORP. For a few hundred dollars automated monitoring can greatly increase your ability to understand your hydroponic crops.

Is ortho-silicic acid worth the additional expense in hydroponics?

Silicon is all the rage right now and different silicon product manufacturers are racing to produce commercial products that contain more and more biologically active silicon. The idea is mainly that potassium silicate – the most commonly used form of silicon in hydroponics – has some problems maintaining high bioavailability at the pH levels used in hydroponics and therefore more stable silicon sources are needed to meet plant needs. However we need to ask ourselves if this is actually true and whether it is actually worth it to go to much more expensive Si sources when supplementing plants with silicon products. Today I want to talk about the Si research up until now and what it tells us about silicon and stabilized silicon products.

–



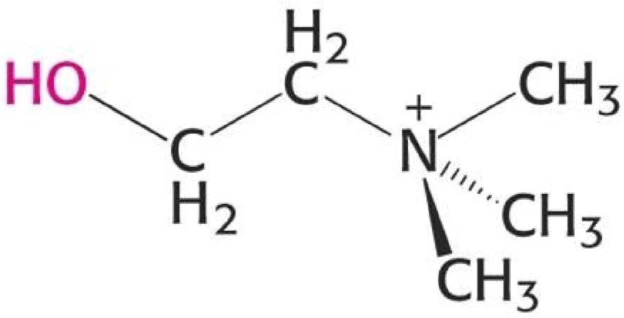
–

Without a doubt there are some proven benefits to using silicon supplementation. As explained within [this recent literature review] from 2015 about silicon’s role in plants the benefits from silicon application include increased photosynthesis, resistance to abiotic stress as well as increased resistance to several fungal pathogens. It is also clear that foliar application of Silicon does not lead to large increases in tissue concentration and root applications tend to yield the biggest benefits. The above image shows some of the benefits of high (1mM) and low Si (0.1mM) treatments under different conditions for hydroponically grown Zucchini plants. The review also mentions the exploration of stabilized silicon forms and the current lack of scientific evidence regarding their efficacy when compared with traditional non-stabilized forms of silicon.

—

So if silicon from potassium silicate can show benefits why may we need a better form of silicon? The problem with silicates is that under low pH values the silicate ion gets protonated and converted into silicic acid but silicic acid is unstable and will tend to polymerize and form molecules with limited bioavailability under these conditions. If we use a form of silicon that does not suffer from this problem then we might be able to get some additional benefits. There are indeed a few studies in lettuce and tomatoes showing that choline stabilize orthosilicic acid (ch-OSA) can indeed improve plant responses under Mn stress and even a study about the use of ch-OSA improving seedling growth but these results lack controls against potassium silicate so we don’t know if the response would simply be equal than that of a traditional silicate application. Below you can see a graphical representation of a choline molecule’s structure, choline is basically a beta aminoacid that is able to stabilize silicic acid by binding to its oxygen atoms through the positive trimethyl amine group, inhibiting polymerization.

—



Choline

–

We know however that not all forms of stabilized silicon sources would work well. For example there is a [study](#) involving alkyl silicic acids (another form to stabilize silicon) that shows that the application of these compounds produces even worse results than controls with no silicon supplementation. Plants do not seem to deal well with this type of stabilized compounds, where the silicon is stabilized by the introduction of simple alkyl groups. Some of these forms of silicon – dimethyl silicic acid – were even highly toxic to plants at low concentrations.

–

Up until this point there is basically no scientific evidence that shows how stabilized silicon sources like ch-OSA may provide a benefit over using a simpler and cheaper source of silicon like potassium silicate in higher plants. If potassium silicate is dissolved at the appropriate concentration and in an adequate manner then there is no doubt that it can provide significant benefits at a fraction of the cost. Companies producing ch-OSA and similar silicon stabilized sources generally say that they contain "more bioavailable silicon" and while it may be true that they may allow for the larger abundance of some silicon species in solution, what they should show is an increase in benefits when compared with a potassium silicate control since this is in the end what interests most hydroponic growers. While this evidence is lacking it is certainly not worth it to pay the extra cost, given that benefits using potassium silicate have been proven while benefits using ch-OSA haven't been proven to be greater than those obtained with these cheaper Si sources.

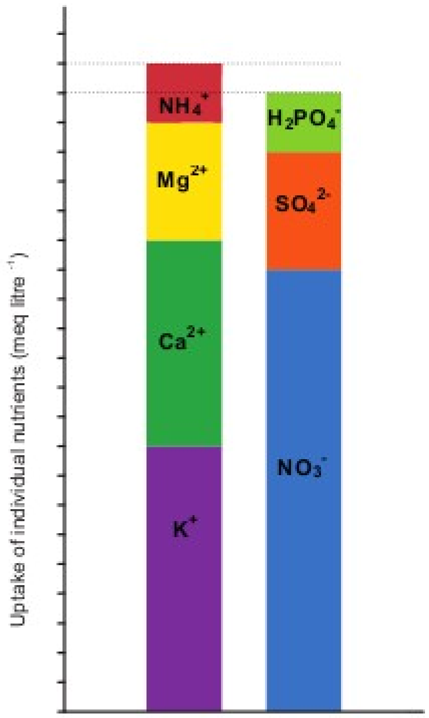
Nitrate, Ammonium and pH in hydroponics

The stability and variability of pH in hydroponic solutions has always been a complicated topic to discuss. There are many reasons why pH may change in a hydroponic system, ranging from the media being used, the micro-organisms present and the amount of carbon dioxide in the air. However the most agressive contributing factor in a healthy hydroponic system with no important pH altering media is plant nutrient absorption. Today we are going to talk about this and how the ratio of ammonium to nitrate heavily affects plant nutrient absorption.

–

FIGURE 6

Balance between the uptake of cations and anions by plants when the NH_4-N/total-N in the supplied nutrient solution is high, thereby imposing a higher total cation uptake in comparison with that of anions



Under these conditions, the pH in the root zone tends to decrease, because the difference between total cation and anion uptake by the plant is compensated for by release of H+ by the root cells to avoid imbalances of their electrochemical potential.

–

As I have discussed in the past in my blog, plants will always compensate ion absorption by releasing a pH altering ion of the same charge. If a plant absorbs nitrate (NO3-) it will release an OH- ion in order to balance the charge. This ion will increase the pH. The same happens when the plant absorbs a cation – like K+ or Ca+2 – as it will release H3O+ ions in order to compensate (one in the case of K+ and two in case of Ca+2). However plants do not absorb all ions equally and therefore if there is more cation than anion absorption pH will decrease while in the opposite case pH will increase.

The image above shows how plants usually distribute their cation/anion absorption. In the case of anions the largest contributing factor is nitrate while in the case of cations the largest contributions come from potassium and calcium. Since adding ammonium to replace nitrate will cause the balance to shift to the cation side we can indeed cause the pH behavior to change significantly by changing the ammonium to nitrate ratio. For many plants – especially fruiting plants like tomatoes or cucumbers – the ideal ammonium to nitrate ratio has been established to be around 2:8 and this usually implies that pH will tend to increase as a function of time since the amount of anions absorbed will be larger. Using larger ammonium to nitrate ratios – like 5:5 – may bring you more pH stability but this may be at the cost of crop productivity. If you want to increase the amount of ammonium in solution ammonium sulfate (shown below) is usually the cheapest source. Adding 0.05g/L (0.18 g/gal) will increase your NH4+ concentration by around 10 ppm.

–

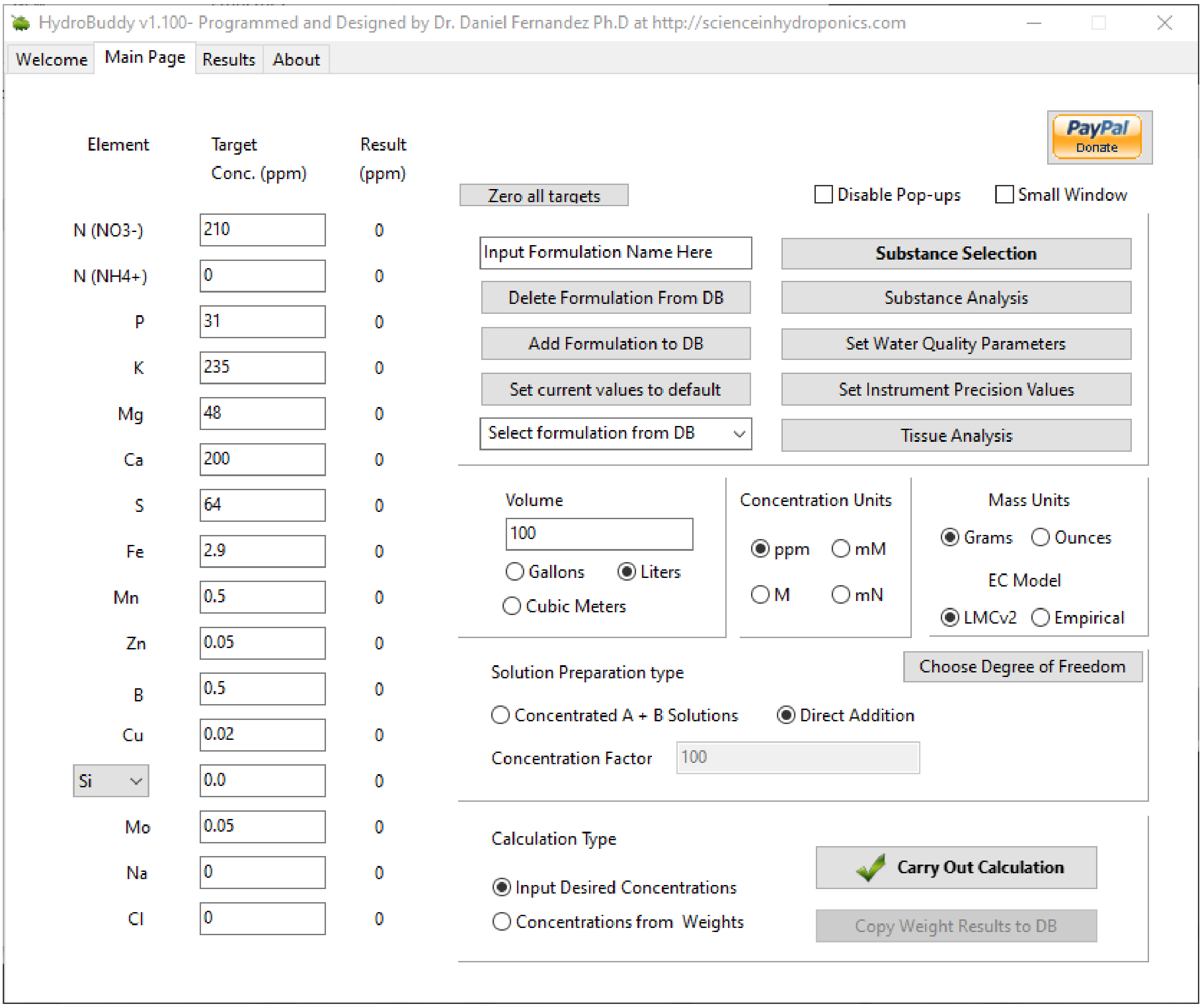
–

It is also important to note that you cannot easily affect ion absorptions by shifting solution concentrations. Ammonium affects the pH quite directly because adding more ammonium to the solution almost immediately adds that ammonium to the plant's cation absorption – because it's taken up very readily – but adding other cations might not increase their absorption because either environmental or plant regulatory mechanisms may stop this from happening. For example increasing potassium may not increase the overall size of the cation absorption column because the plant might simply compensate by reducing calcium absorption. Such a compensatory mechanism does not exist for ammonium, reason why it is so effective in changing the relative size of one column against another.

In the end the nitrate/ammonium ratio is perhaps one of the biggest weapons you have in controlling how your plants change the pH of your nutrient solution. However aiming for the most stable pH – in terms of cation/anion absorption – might not be the best bet since this might reduce your crop's yield. At optimum nitrate to ammonium concentrations most crops tend to experience some moderate pH increases as a function of time. Nonetheless different crops respond to ammonium to nitrate ratios differently so you might want to give different ratios a try to see what works best for you, both in terms of yields and easiest crop management.

HydroBuddy v1.100 : The First Free Open Source Hydroponic Nutrient Calculator Program Available Online

HydroBuddy is a completely free and open source program for the calculation of nutrient solutions for hydroponics and general agriculture built by me – Daniel Fernandez – based on my experience in hydroponics as a professional chemist. This piece of software was coded from the ground up using the Lazarus open source programming suite and implemented using appropriate database solutions as well as a powerful linear equation solving algorithms from AlgLib. HydroBuddy binaries are available for Linux, MacOS and Windows. HydroBuddy is released under the GPL license.



HydroBuddy v1.99 running on Windows

These are some of HydroBuddy's features :

- Calculates the weights of specific substances needed to arrive at specified concentrations of different elements (formulation to salt weights calculation)
- Easily fine tune your salt weights after calculations.
- Contains library with commonly available fertilizer salts (new in v1.7)
- **Leaf tissue database and conversion to concentrations needed in solution based on water use efficiency equations (v1.99)**

- Raw salts in the included DB have links to help new users know where to buy them (accessible by clicking the salt name in the results tab). Please note these are amazon affiliate links that support the development of the software at no extra cost to you. (new in v1.7)
- Includes ability to save and load lists of substances used for calculations. (new in v1.7)
- Empirical model for the prediction of EC (new in v1.8)(read more here)
- Figure out the nutrient contribution from different acids to neutralize different levels of total alkalinity (v1.95)
- Calculate the percent composition of the solid mix used to prepare a given solution (v1.95)
- Program state is completely saved when the application is properly closed (v1.95)
- Calculations in ppm, mmol/L, mol/L and meq/L.
- Calculate liquid additions in mL and add any custom substances as liquids
- Edit the percentage elemental composition of each substance or add new ones to fit your needs
- Powerful open source linear equation solver provided by AlgLib
- Always tries to find the best mathematical fit to a formulation by a given group of substances
- Allows to get the concentration values for the addition of a certain specified amount of substances (salt weights to formulation calculation)
- Easy-to-use interface for the addition, edition and assignation of substances to calculations
- EC prediction module based on limiting molar conductivities, ionic strength and ion charge (new in v1.9)(read more here)
- Use the resulting weights of a formulation calculation to perform a calculation of the opposite nature and vice versa (easily allows you to see the effect of manual modifications)

- Calculations for both direct additions and A+B concentrated solutions
- Use any custom substance as a part of an A+B concentrated solution calculation
- “Substance Analysis” module which allows you to analyze different substance, it can be used to figure out the ppm contributions of commercial fertilizers.
- Water quality module allows you to include water quality analysis within the calculations
- Adequate implementations of instrumental and gross errors with custom instrument precision input
- Proper database implementation allows you to easily save your custom formulations
- Set default water quality and data log data sets that load automatically on program startup
- Save and load formulations using any concentration unit.
- Choose between grams or ounces
- Choose between liters, gallons and cubic meters for volume inputs
- Export calculation results to a CSV file
- Tutorial tabs showing and explaining the main features of the program !

The program allows anyone to easily carry out calculations for the preparation of nutrient solutions, a very cumbersome task that can take a lot of time and effort when done manually. **If you’re having trouble with HydroBuddy and you would like to purchase support please email me by using the contact form with your requirements to receive a quote**. **If you are using HydroBuddy for academic purposes please cite its use as follows:**

Daniel Fernandez Pinto, "HydroBuddy: An open source nutrient calculator for hydroponics and general agriculture", v1.100, url: https://github.com/danielfppps/hydrobuddy*, 2022*

If updating from an old version by replacing only the executable, make sure you delete all the csv and ini files

within the folder to avoid configuration issues.

Versions are numbered sequentially (v1.96, v1.97, v1.98, v1.99, v1.100…). Version v1.100 is the last version available.

You can download the program binaries through the following links:

Get HydroBuddy for Windows

Just unzip the program and run the hydrobuddy.exe file. Binaries provided are 64-bit. For 32-bit binaries please compile from the source on the github page.

Get HydroBuddy for Linux

Unzip, then make sure you execute "chmod +x hydrobuddy" within the folder so that you can execute the program.

Get HydroBuddy for MacOS

Unzip all files into a folder, then run the app file. If you get a permissions error message, go into the hydrobuddy.app/Contents/MacOS folder in a terminal and execute the command "chmod +x hydrobuddy". If you get an error about the app author, hold the control key while launching the app. Note that you will need to select the HydroBuddy folder each time you start the program. This binary was compiled in MacOS Monterey.

Get HydroBuddy Source

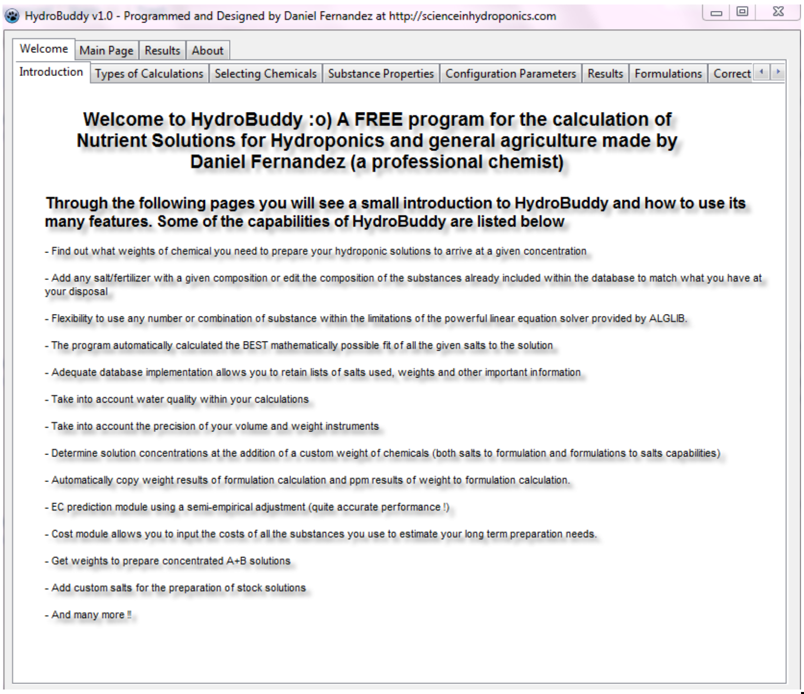
A simplified version of the program with most of its basic functionality is also available on Android. You can get it through the google play store by using the link below:

Get HydroBuddy for Android

Almost There Guys ! The New HydroBuddy v1.0 is Just Around the Corner :o)

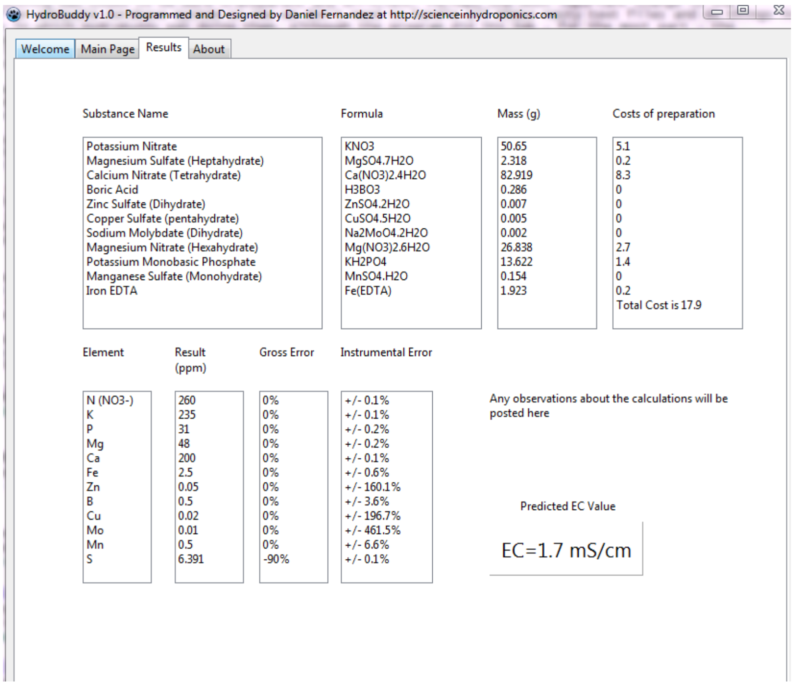
Through the past few months its been very quiet here at scienceinhydroponics.com mainly because I have been very busy with the development of the latest version of HydroBuddy as I mentioned within my last post. Through the past few weeks I have worked many hours on this new implementation and I am glad to say that the results are almost ready for me to show :o) Within this post I will talk to you about some of the many improvements of this new version of HydroBuddy as well as what I will be removing, some of the changes I have introduced and the many and great advantages of this much more robust program.

The first thing I want to mention – which I am very happy to announce – is that HydroBuddy has now been coded again (from the ground up) so everything is new and done in a much better way :o) Probably many of you will be happy to know that HydroBuddy has been in fact implemented within Lazarus, making it available now natively on Linux and Mac as well as Windows. Although I haven't tested the Mac or Linux binaries I can say that it doesn't use any windows proprietary components so it should work right away on most regular linux and Mac implementations.



There are certainly a ton of improvements that I have implemented within this new version of HydroBuddy, redesigning the way in which everything was coded to be more transparent and efficient. Perhaps the most important change is the implementation of an adequate database system so now we don't need to handle all those nasty text files and do things in the primitive way in which HydroBuddy was doing them. Although the program did its job – for the most part – the implementation was too inflexible and everything was "hard coded" – so to speak. The new database flexible implementation allows you to add or edit the composition of any of the salts included within the program and even to use custom salts within concentrated solution preparations.

The next improvement – which is the one I like the most – deals with the introduction of a much more powerful linear equation solver which allows us to fully exploit the power of our computers to carry out the simulations. Previously HydroBuddy used a very primitive solver which was "scotch tapped" with many different manual rules to make it yield adequate results. Of course the problem of this – as many of you discovered – was that HydroBuddy was "picky" about its choices and it wouldn't use two salts with Mg – for example – if it was already using one. Now the new solver is a very powerful AlgLib implementation which allows the program to find the best mathematical solution for a formulation, making sure that you get the absolute best possible case out of all the salts you choose.



The "salts used" tab has also been eliminated in favor of a much more convenient implementation which allows you to simply select salts from a list and set which ever values you want. Another advantage of the database implementation is that any choices you make will be saved and there for you when you reopen HydroBuddy. The program also implements database components to save formulations, water quality parameters, etc, making it much easier to get into previously saved data without the problem of having to read text files (which was a very bad decision for HydroBuddy in retrospective).

Another things you guys might like a lot is that I have added "hints" to almost all important buttons so hovering your mouse over things will now make them show you what they do. Another improvement is the addition of a tab with descriptions and tutorials, allowing you to get to know the software very well without having to open up a website, "copy and paste URLs" or any other such stuff.

To sum it up, HydroBuddy v1.0 is coming and it will be a very positive change for this very useful – at least in my opinion ! – piece of software :o). The fact that all software components are much more transparent now will also make it much more eligible for academic use, something which I also want this program to be about :o) So its coming ! And its coming soon !

Walking Towards v.1.0 : Why Development of HydroBuddy is Taking Its Time

If you had been following my development of the free HydroBuddy nutrient calculator your probably have wondered why development seems to have “stopped” during the past few months. The truth is that beyond the fact that I have been quite busy – with my other occupations – I have actually decided to implement some very large changes to HydroBuddy before version 1.0 comes out. On today’s post I will take some time to discuss the changes I will be implementing and what these changes will bring when v.1.0 finally comes out, probably in January-February 2011. I will talk about the current problems on the calculator and what solutions I am working on.

–

HydroBuddy is currently a stand-alone free hydroponic nutrient calculator which anyone can use. It is a simple tool for the calculation of nutrient weights or the reverse-engineering of commercial nutrient solution allowing users to perform a ton of analysis without too many complications. However the software does have a few problems which I believe need to be solved if HydroBuddy is to become the most complete and BEST hydroponic nutrient calculator online (even when compared amongst commercial ones).

The first big problems that come from HydroBuddy lies within its software implementation. The program was built within Delphi 2010, reason why compatibility with other operating systems is minimal (if available at all). For this reason I have decided to port the whole program into Lazarus, allowing me to get full Linux and Mac versions released from v1.0 onwards without any further problems.

The second – and perhaps the biggest problem – in HydroBuddy, is the way in which the calculations and database were implemented. HydroBuddy doesn’t use a formal database but a series of arrays which it uses to calculate/store the solutions to the problems its presented with. The new version will include a proper database engine which will allow us to greatly expand the scope of HydroBuddy, this will also allow me to solve another problem which makes HydroBuddy “miss” some solutions if combinations of certain salts are used. By implementing a proper database and powerful linear equation solvers the new version of HydroBuddy will be much more powerful and good enough to become a standard for not only hobby but many scientific applications.

As you see, the above changes require me to practically reimplement the whole program but certainly they are worth making since they will make HydroBuddy’s core much more robust than with its current implementations. With this HydroBuddy will be able to easily store much more data, solve problems much more accurately and become much more “user friendly”. It will certainly take me some time – as I only do this development when I have free time – but it will definitely pay off in the end as it will be a free solution for anyone looking for a software package to help them calculate their nutrient solutions.

In the meantime feel free to use the v0.98 of HydroBuddy which already solves many of the problems of nutrient solution making and allows anyone to prepare their own hydroponic solutions without having to perform any manual calculations :o) Thank you very much for all your support and interest !

Instrument Precision : Its Importance in the Preparation of Hydroponic Nutrient

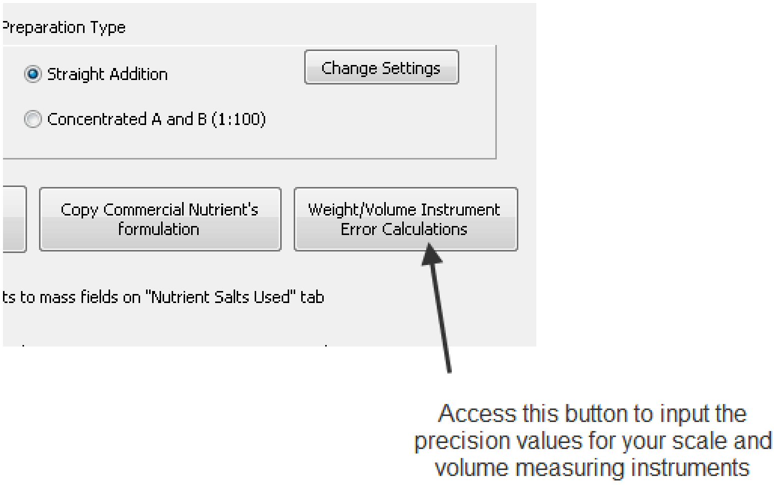
Solutions

One of the most overlooked aspects when preparing hydroponic nutrient solutions is the actual precision of the instruments used to measure the salt or liquid reagent additions. People who are not familiarized with the preparation of solutions usually underestimate the importance of this aspect of solution making – both concentrated and final – which is absolutely vital for the accurate and reliable preparation of solutions. On today's post I will attempt to explain the concept of instrument precision, the errors caused by this fact and how they are calculated by HydroBuddy to give us an idea of how dependent our calculations are upon our instruments. After reading this article you will be able to know if the instruments you are using for your solution preparation needs are adequate or what you need to do in order to ensure that the preparation of your solutions remains reasonably accurate.

What is instrument precision ? This point is best illustrated by a practical example. Imagine that you are using a ruler to measure the length of a simple pencil. A common ruler (in metric units) generally has large divisions (in centimeters) and smaller divisions (in millimeters), when you measure the pencil you will note that the length of the pencil will be between two of the finest divisions – or very close to one – but you will not be able to determine the measurement beyond this accuracy. For example if the measurement of the pencil is between the 2.3cm and the 2.4 cm line you can say that the pencil measures 2.35 +/- 0.05cm this means that we can be absolutely sure that the pencil has a measurement between 2.3 and 2.4 cm but our instrument does not allow us to "see" any further. In this example the three digits of the measurement are called "significant figures" while the last one is called the "measure of uncertainty" since it is a value we can only be certain about within a certain threshold.

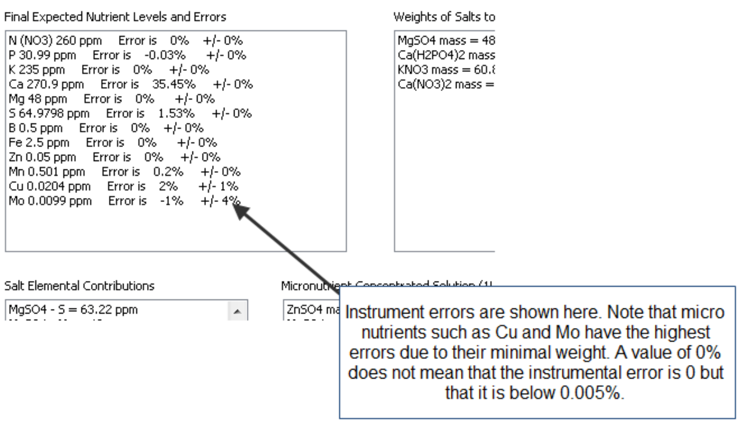
When you measure your hydroponic solutions you need to use instruments to weight your salts or liquid fertilizers and you also need to measure the volume of your solutions (either concentrated or final). When you weight your salts your scale will have some uncertainty (usually represented as the point value of the last digit) so for example if your scale displays a weight for a salt of 5.50g the actual measurement is 5.50+/-0.01g as – in analogy with the pencil example – the scale cannot determine the latest digit beyond a certain threshold. The problem with this is that if your salt's weight is in the vicinity of the scales last digit your uncertainty will be a big magnitude of what you want to weight. For example, if you want to weight 0.05g of a salt with the above scale the uncertainty of instrument will be +/- 0.01g so you will effectively have an instrumental error of +/- 20% of the salt's mass, meaning that your final concentration will probably be VERY deviated from what you intend to measure.

Another important factor is the precision of your volume measuring gear since errors add up as you continue the preparation. If you can measure the volume of your reservoir with a precision of +/- 1L the you need to prepare at least 100L such that the error you get from the measurement of your nutrient solution's volume is not greater than 1%, however if you are preparing a concentrated nutrient solution (for 10L for example) you will need to use a more precise method of measuring volume, an instrument with a precision of at least +/- 0.1L. If you are uncertain of what the precision of your volume instruments are then you need to look at their graduation, the precision of a volume measuring instrument can usually be approximated to half its finest graduation. If you are measuring volume -for a concentrate solution for example – with a cup that has a line every 100mL then your precision is +/- 50mL (or +/- 0.05L).



The above picture shows you where you can change the precision of the instruments used within HydroBuddy so that the program can calculate the error caused by your instruments in your preparation. Some people may have noted that when calculating “direct additions” there is no instrumental error while when calculating concentrated solutions there is, this is associated with the precision in volume since when straight additions are made the amount of volume that needs to be measured is MUCH higher while for concentrated solutions a much more precise volume instrument is required (depending on solution volume) since the volume is lower.

_



If you get very large instrumental errors (for the calculations you are doing) then there are several things you can do to correct them. The first is to prepare large amounts of concentrated solutions since the amount of salts weight will be much larger. Preparing 20L of a concentrated solution with a 1:200 concentration factor will allow most people to weight their salts in a scale with a 0.01g precision while other solutions -such as using the direct addition methodology with concentrated micro and Fe solutions – are also possible. In the end you need to take very good care of instrumental errors and take them into account since they will determine the final accuracy of your nutrient solutions. For macro nutrients the errors shouldn't be above 0.05% while for micro nutrients such as Mo and Cu, errors as high as 20% can be tolerated since higher precision would require the use of much higher purity salts since these elements are also possibly contained as impurities within other salts (meaning that salt purity becomes a higher factor than instrumental error below 20%).

Understanding Reagent Purity and Its Importance in Hydroponics

When making hydroponic nutrient solutions one of the most important concepts we need to understand is "reagent purity" and how this affects the overall quality and composition of our hydroponic nutrient solutions. People who have not been academically trained in science usually do not have a very good understanding of this concept and its implications and how they need to take it into account when doing their hydroponic formula calculations. HydroBuddy – my free hydroponic nutrient calculator – allows the user to specify the purity of all the reagents used in the preparation of nutrient solutions so that accurate and adequate calculations are done. What does purity mean ? How do you determine the purity of the reagents you want to use ? What does a 100% purity mean ? Keep reading the following few paragraphs to find out.

What is reagent purity ? Imagine that you have 80g of a pure substance – table salt for example – and you mix it up with 20g of sand. The original salt – which was pure – was 100% table salt while the new resulting mixture is only 80% table salt. This degree of presence of a given “pure substance” with a defined composition within a mixture is what we call the “purity” of a reagent. The objective of purity is to know how much of what you are buying actually fits the chemical composition of what you intend to buy and how much is “other stuff”. The nature of impurities -what is different than what you intend to buy – is different depending on the fabrication process and intent of the reagent you want to use. The nature and amount of these impurities may sometimes be very important while other times it can simply be neglected.

People who are not familiar with this concept generally get confused when people start to talk about the composition ratios of pure substances. For example iron EDDHA is an iron complex which contains about 7% iron. This does not mean that EDDHA is only 7% “pure” but it means that within this pure substance iron accounts for 7% of the weight. The purity of the reagent does not have ANYTHING to do with the composition of the pure substance you intend to get – the iron EDDHA in the above example – but it refers to other things that might be present with what you intend to buy due to the fabrication process. So for example you can can buy Iron EDDHA 7% with a purity of 98% which means that from every 100g, 98g are iron EDDHA with a 7% iron content while 2g are made up of other substances with undetermined composition.

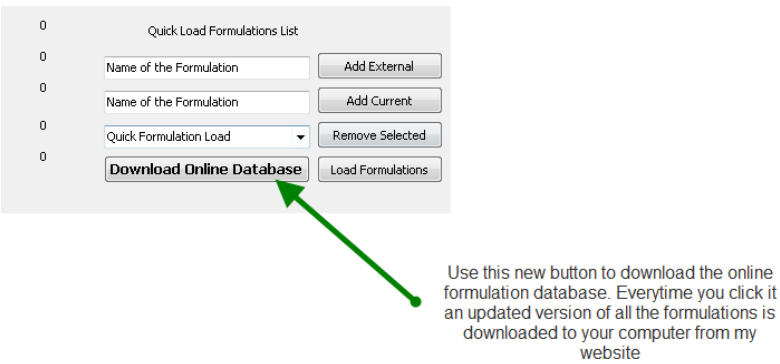
In hydroponics we want to provide our plants with the correct amount of nutrients and for this reason we must make sure that we provide what our formulation demands as a minimum. For this reason when preparing hydroponic nutrient solutions we must always use salts with purity levels above 95% with levels above 98% being better. Salts that are 98% pure aren't very expensive while the purer grades – used for the biochemical and fine chemical industries – are generally several orders of magnitude more expensive. While you can get a calcium nitrate ammonium double salt with a purity of 98% for just a few dollars per kilogram a single kilogram of this chemical at a 99.999% purity (which is often considered analytical grade) would cost around one thousand dollars. This difference in cost arises because as a salt becomes purer, eliminating the small impurities becomes harder and harder. Salts for which extremely high purity levels are achievable (such as NaCl which can be purified to almost 100%) are known in chemistry as "primary standards" because their composition is known to an extremely high degree.

When preparing hydroponic solutions we should not be worried that much about getting very expensive reagents as the impurities we get and the errors we have in our composition are not bound to affect our plants significantly, however we should take them into account so that we know exactly how much of what we know is pure is being added. So even though a reagent may have a purity of 98%, taking into account this will allow us to add enough so that we are certain that at least certain concentration levels are achieved. Of course, using a 100% purity for the reagents is not bound to increase tremendous error if the actual value of the purity of the salts is unknown but making sure that the purity is above 95 or better 98% is always something that should be done to ensure that high quality preparations are being done. You should also understand that the impurities within your salts might actually be insoluble so some small fractions of the salts may remain undissolved when concentrated nutrient solutions are prepared.

HydroBuddy's Online Hydroponic Formulation Database

There are certainly thousands of different ways in which a hydroponic nutrient solution can be prepared. You can make a solution schedule to closely follow the environmental and growing conditions of a certain crop – like tomatoes – or you can simply make up a generic formulation to use within all your hydroponic plants. Besides this we also have an incredible amount of commercial formulations you would perhaps like to imitate and a ton of ways in which you can experiment with nutrient ratios to improve things such as the flavor, size and production of your crops. Since there are so many ways in which we can prepare nutrient solutions I have decided to create an Online Nutrient Database we can use to store and easily access all this information.

My hydroponic nutrient calculator – a.k.a HydroBuddy – has the ability to save and load formulations for the creation of almost any hydroponic nutrient solution. Since the calculator has the ability to grab external files and load them into its internal database I saw no reason why we couldn't create an online database in which we could keep a global record of all the formulations we find and develop. The calculator – since v 0.95 – includes a "download online database" button which downloads all the formulations kept within the online database to the grower's HydroBuddy program. This way the user doesn't have to keep on downloading the database manually but simply by pressing a button all the information is automatically re-downloaded and updated. Added to this is the benefit that the users other loaded formulations remain intact as the calculator detects which formulations are downloaded and which ones were created by the local user.



The idea of this online database is to put all the information available about nutrient formulations into one place so that people all around the world can benefit and experiment with different setups. Added to this is the ability to make the imitation of commercial formulations even easier since the formulations can be kept within the online database. So in my mind it is a win-win situation for everyone, we get to have the opportunity to create a unique database filled with information about solutions from both empirical, commercial and academical sources while we retain the flexibility to use them or modify them within HydroBuddy as we please. This also makes the standardization of formulation use much easier since you can easily tell people what HydroBuddy database formulation you are using and they can easily then reproduce what you have or change it slightly to fit the nutrients available in different regions of the world.

How can you contribute to this database ? **In order to add a file to the database you need to send me an email to dfernandezp(at)unal.edu.co** , you need to include the name of the formulation you are adding, its intent and source (what plant or if its an imitation of what commercial fertilizer) and a file created by HydroBuddy with the necessary information. In order to create this file just save the formulation on the “Desired Formulation” tab then send me the file created within HydroBuddy’s directory. After you send me your contribution I will add it to the Online Database so that everybody will be able to download it with the click of a button.**If you want to send many files just put them all within a zip files so that they will be easier to download from my email client, include in the body of the email the necessary descriptions for each file as detailed above.**

So if you have been waiting for an opportunity to contribute to HydroBuddy feel free to share with me any formulations you might have found or created that you would consider useful for someone. If you have spent a lot of time taking the formulations of commercial nutrients and translating them into HydroBuddy you can now share this knowledge with the rest of the world. I will also do my fair share to add new formulations to the online database, particularly regarding academic sources since most people do not have access to the research databases where the articles detailing them can be found.

If you want to contribute and support HydroBuddy but you do not want to send any formulations feel free to donate using the paypal donate button on the left hand sidebar :o)

Hydroponic Nutrient Availability : What “Pushing Out an Element” Really Means

Plants need a very large variety of elements in order to grow successfully. In hydroponic crops we intend to provide all these elements in their different forms dissolved within our nutrient solutions. However the mechanisms by which plants absorb these elements is complex and there are many different factors that determine which elements are absorbed and which elements are not. On today’s post I will write a little bit about the problem of nutrient availability, what factors determine how ions are absorbed and what does it mean to “push an element out” when talking about a hydroponic system. First we will talk about the nature of the elements dissolved in hydroponics solutions followed by the importance of environmental conditions and nutrient interactions that finally determine the actual availability of nutrients for plant growth.

The first important thing we need to understand is that plants can absorb many different forms of the elements we need to provide and that these elements are not absorbed in their pure state but forming ionic entities dissolved within our solutions. For example nitrogen is absorbed by plants as the NO3(-) ion (nitrate) or as the NH4(+) ion (ammonium), both of these ions supply the plant with nitrogen but their overall effect is different and the ratio of their concentration has an important effect on plant growth and development. The second thing we need to understand is that plants can only absorb things that are dissolved in solution and that plants cannot absorb materials that are above a certain size.

Although studies have shown that plants can take large particulate aggregates (such as polyoxometalates) it is true that large bulk solid materials of a few microns in diameter are already beyond the cellular absorption capacity of most plants. In order for something to get into a plant it needs to be dissolved in water, it needs to form the ionic entities which are assimilable by the plants.

The third and also probably least understood aspect of nutrient absorption is that the chemistry that leads to the entering of a nutrient within the plant cells must be favorable. What this means is that different conditions must be met so that plants can get their nutrients. There are many things that can cause this process to fail which may not be related with the nutrient itself but with the presence or absence of another nutrient. In plants there is an agonist/antagonist relationship between the different ionic species such that the excess or absence of one specie affects the absorption of another. For example iron is absorbed by plants as either Fe(2+) or Fe(3+) while phosphorous is generally absorbed as H2PO4(-) or HPO4(2-), when there is an excess of phosphate species the formation of iron-phosphate crystals can happen within the plant's nutrient transport system causing what seems to appear as an iron deficiency. The problem is not caused by a lack of iron but by an excess of phosphate that hinders the mechanisms of absorption.

Increasing iron concentration when this happens merely makes the problem worse as when phosphate concentrations lower an excessive iron concentration – now causing iron toxicity – is present.

The key to have a healthy plant with adequate absorption of nutrients is therefore to make all the necessary above mentioned conditions adequate. The first thing we need to do is guarantee that the nutrients we provide are in the adequate form (ionic species) and the second is that the conditions are adequate so that these species do not change but instead are absorbed. This leads us to the problem of "nutrient push-out" which is mentioned a lot within the hydroponic community. There are several environmental conditions that can cause the assimilable ionic forms of nutrients to change to something else therefore being "pushed out" of a solution. For example if you have high carbonate ion concentrations within your water the addition of your hydroponic nutrients can cause iron carbonate precipitation. This means that the previously dissolved iron (available as Fe^{2+}) now becomes bound to carbonate ions forming a solid ($FeCO_3$). This solid is very stable and hence doesn't form aqueous ions but instead stays undissolved in the bottom of your nutrient solution. Other things such as an increase in pH (which precipitates metal oxides like $Fe(OH)_2$) can also dramatically affect nutrient availability.

Many people tend to believe that calcium and sulfate precipitate easily but a careful analysis of the solubility behavior of calcium sulfate reveals that you would need a concentration of sulfur as sulfate of more than 400 ppm before any precipitation actually happens. In most cases precipitation can happen if concentrated solutions are mixed too quickly one after another – without adequate dissolution – or if a mix of solid nutrients is added to the reservoir. However this precipitate formed is often later dissolved with time as the aqueous solution reaches equilibrium.

In general when people refer to an element being “pushed out” they talk about the element being made unavailable to the plant through some mechanism generally involving the formation of a stable solid that cannot be used by the plants. The solid “drops out” of the hydroponic solution and therefore the term “pushed out” was born as a way to refer to this phenomena. Nonetheless it is always important to remember that other things can cause elements to become unavailable, such as temperature and the concentration level of other elements. In hydroponics we are dealing with a very complex interaction between ions and plants and our main goal is to keep the different nutrients balanced in such a way that most interactions are beneficial. Keeping an eye on temperature, pH, nutrient ratios and water quality is vital to achieve this desirable outcome.