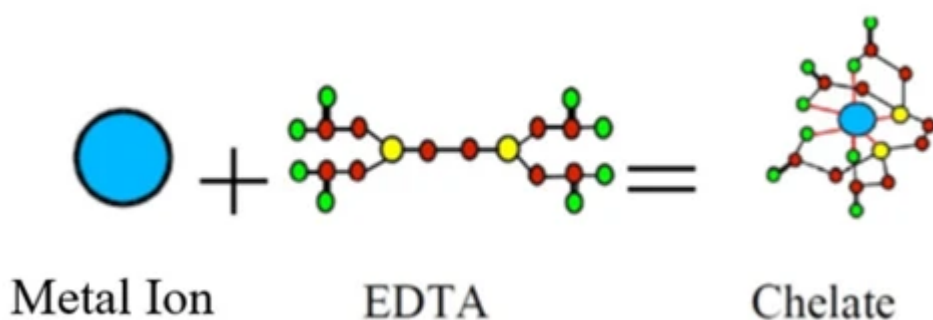


How to prepare a low cost chelated micronutrient solution

Micronutrients constitute only a small portion of a plant's nutritional requirements but are still vital to growth and development. They are mainly comprised of heavy metals (Fe, Zn, Mn, Cu, Mo) as well as a single non-metal, boron (B). Since they are used in such small concentrations – normally in the 5 to 0.01 ppm range – they are normally put into concentrated nutrient solutions in small proportions and included with other components such as Ca and Mg, which are present in concentrations much more in line with macro nutrients like N, P and K.



Simple model of the metal chelating process

The advantage of micro nutrients is that they are available cheaply and in high purities as heavy metal sulfate salts. These however have the problem of leading to relatively unstable cations in solution, making the preparation of concentrated micro nutrient solutions with pure sulfates impractical (unless you want to see how a gallon of rust looks like). However we can chelate the cations as they come out of these sulfates, using a chelating agent, in order to prevent any precipitation issues. In this article I am going to walk you through the preparation of a DIY chelated micronutrient concentrated solution. This is much cheaper than buying the

heavy metal chelates, which can be 3+ times more expensive. To prepare this solution you'll need to buy the chemicals shown in the table below. The table includes links to buy all the different substances mentioned plus their cost (without shipping).

Link	Price USD/lb	Weight g/gal
Disodium EDTA	22.96	17.0600
Ferrous sulfate heptahydrate	15.99	9.4211
Zinc sulfate monohydrate	9.49	0.1039
Manganese sulfate monohydrate	14.99	1.1646
Copper sulfate pentahydrate	20.99	0.0595
Sodium Molybdate	19.99	0.0191
Boric acid	10.95	3.3384
Total Cost	115.39	

List of salts to prepare a DIY chelated micronutrient concentrated solution. This concentrated solution is to be used at 5mL per liter of final feeding solution.

In order to prepare the solution you also need a scale that can weight with a precision of +/- 0.001g ([this is my low cost recommendation](#)) and a container where you can store 1 gallon of solution. Please note that these solutions *have to be prepared with distilled water*, with R0 water you might still run into some issues in the process. To prepare the solution carry out the following steps (the weights to be used are specified in the table above):

1. Wash your container thoroughly with a small amount of distilled water
2. Fill your container with half its volume of warm distilled water (30C, 86F)
3. Weight and add the disodium EDTA, stir until it is completely dissolved (this can take a while).
4. Weight and add all the remaining micro nutrients one by one in the order given above, stirring till each one is

- fully dissolved before adding the next.
5. Fill the container to its final volume using warm distilled water.
 6. Let the solution cool before closing the container.
 7. For longer half-life transfer to a container that is opaque to UV light.

This solution is prepared to give you the heavy metal concentrations of the [Hoagland nutrient solution](#) (a very common set of ratios used in scientific research for growing plants) when used at a ratio of 5mL per every liter of final feeding solution (18.92mL per gallon). The links given above are for 1lb of each product, with this you should be able to prepare at least 53 gallons of the concentrate, which will allow you to prepare 10,600 gallons of final feeding solution. The first salt you will run out of is Fe, but some are used so sparingly that you should be able to use them for the rest of your life without needing to buy any more (like copper sulfate and sodium molybdate). For less than 120 USD you will be able to have enough solution for probably the rest of your life – if you're a hydroponics aficionado – or even an entire crop cycle if you're a commercial grower.

This preparation is not without problems though, since the chelates are all prepared *in situ* they will take a substantial amount of time to reach their thermodynamic equilibrium, meaning that it cannot be used too soon or some of the metals might not be fully chelated. To obtain the full metal chelating effect an excess of around 25% of disodium EDTA is also used, which means that this micro nutrient solution contains more free EDTA than a solution prepared with the chelates. Another issue is that all heavy metals are chelated with EDTA, which might not be optimal depending on your growing conditions. The EDTA chelates are also less stable against UV light and are also more easily attacked by oxidants. Another final issue is that the solution above contains no preservatives and fungi generally like to feast on

this sort of micronutrient containing solutions. It is therefore reasonable to avoid preparing any large amounts of the above, as a solution prepared as instructed is normally expected to spoil in 3-4 weeks.

With this in mind, the above is not a perfect but a low cost and practical solution for those who want to start preparing their own nutrient solutions and avoid paying the high prices of some commercial nutrients just because of their micro nutrient contents. The above gives you a versatile micro nutrient concentrate that is bound to be adequate for growing almost all plants.

Why TDS is NOT equal to Total Dissolved Solids in hydroponics

Electrical conductivity is a very commonly used measurement in hydroponics, yet a very poorly understood one. I have written several posts about conductivity in the past ([1](#),[2](#),[3](#)) and today I want to talk about the use of the term “Total Dissolved Solids” and the poor usage of the unit “ppm” in order to express a measurement of electrical conductivity. In this article I will walk you through why this term exists in the first place and why its use in hydroponics is terribly misleading for growers.

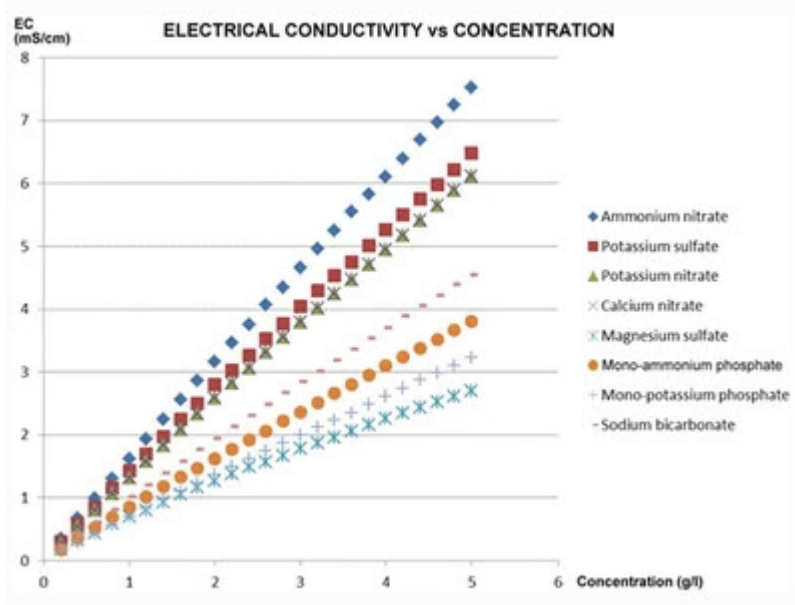


Conductivity as a function of NaCl concentration (taken from [here](#))

Conductivity is just a measure of how easy it is for an

electrical charge to go from one electrode of a certain area to another. It's generally expressed in mS/cm, which is a measurement of conductance (the opposite of resistance) and area (the area of the electrode). How in the world do we get from this to a measurement like "ppm", which measures the concentration of something in mg/L? What does a measurement of 500 ppm even mean? What is it that we are expressing a concentration of?

The answer lies in the practical uses of conductivity and a simplification to make the evaluation of water sources easier. Conductivity is generally linearly proportional to the amount of a pure salt dissolved in solution at low concentrations. For a pure salt like table salt (NaCl) the higher the concentration of the salt in solution the higher the conductivity (you can see this in the image above). People working on water quality realized that they generally dealt with similar salt combinations (Mg and Ca carbonates and possibly some Na and K chlorides) so they decided to use some standard salt mixtures (say KCl, NaCl or some mixture of Ca/Mg/K/Na salts) and then use conductivity as a proxy for the concentration of these things that are actually in solution. So the "ppm" that your EC meter reads is just the equivalent conductivity of some standard. A meter reading 500 ppm in conductivity is telling you "your solution has the same conductivity as a solution of the standard at 500 ppm". The "standard" can change – as mentioned before – which is why there are several different TDS scales. One meter might be telling you it's the same conductivity as a solution of KCl with that concentration, while another might be in NaCl.



Conductivity curves of different salts used in hydroponics (taken from [this article](#))

The above is very useful when you're measuring things that tend to be similar but this becomes a complete nightmare when the composition of what you're measuring can change substantially. *In hydroponics you have a wide variety of different salts, all with very different conductivity values at different concentrations.* Look at the graph above, which shows the conductivity as a function of concentration for 8 different salts commonly used in hydroponic culture. If you prepare three solutions, one with 1000 ppm solution of potassium sulfate, another with 1000 ppm of monopotassium phosphate and another with 1000 ppm of ammonium nitrate and measure them with your conductivity meter they would *all* give very different results. The meter might be close to 0.95mS/cm for the monopotassium phosphate, but it might read almost 1.5 mS/cm for the potassium sulfate. Both solutions have 1000 ppm of "total dissolved solids" but the conductivity meter is telling you one has 500 ppm and the other almost 800 ppm, none of them even close. This is because "total dissolved solids", as used in water quality measurements, is a meaningless measurement in hydroponics as it relates to the actual ppm values of things dissolved.

This is the main reason why you should never compare the EC

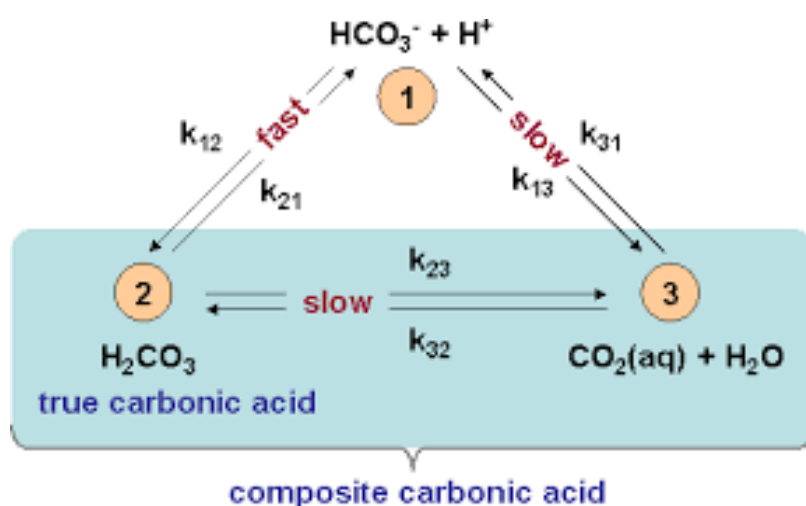
values of nutrients that contain different ratios of salts, because they are simply not the same. One nutrient might give you 100 ppm of potassium at some EC level, while another might give you 200 ppm. Thinking that having the same EC level means that both are at the same “strength” is a big mistake, since this is never going to be the case when two nutrient solutions are mixed with different ratios of nutrients. This is also why comparing vegetative and bloom formulation EC values is not correct. A solution in veg might contain a lot more of nitrates while a solution in bloom might contain more phosphates. As we saw above this might mean that a solution of the “same strength” might actually have a significantly lower measured EC value.

Since the TDS measurement is not telling you anything about “total dissolved solids” in hydroponics, you should avoid using it to avoid confusion. This is important since nutrient concentrations are usually expressed in ppm as well, ppm of actual nutrients dissolved in solutions. Instead use the normal conductivity measurements of your meter in conductance per area. You should also take care to only use EC values to talk about comparative strength when you’re talking about a formulation where the ratios of nutrients remain the same. If that’s not the case, then you should not talk in comparative terms between the two solutions as this might deviate a lot from reality.

My advice is to not think in EC terms to begin with, but to think about nutrient concentrations, prepare solutions that match the concentrations you want and then use the EC of those solutions as references to know whether they are prepared correctly or not. The conductivity should be a measurement used for confirmation but not as a guiding principle. For example the aim should be to “prepare a solution containing 150 ppm of N and an K:N ratio of 1.2” not to “prepare a solution with an EC of 1.2 mS/cm”.

Understanding the carbonic acid/bicarbonate buffer in hydroponics

I have written several articles before about pH and its importance in hydroponic culture ([1](#), [2](#), [3](#), [4](#)). However I have yet to write a detailed explanation of one of the most important buffering systems in hydroponics, which is the carbonic acid/bicarbonate buffer. This buffer is significantly more complicated than the simpler buffer created using phosphoric acid species, as it not only relies on ions present in solution but also on the partial pressure of carbon dioxide in the atmosphere. In this article I will attempt to explain this buffering system in detail, shining some light into the limitations of this buffer and how changing different key variables can fundamentally affect the way it works in hydroponics.



Chemical reactions involved in the carbonic acid/bicarbonate buffer. Taken from [here](#).

A buffer is nothing more than a pair of chemical species in solution that are present at a certain pH, that can react with

additional H_3O^+ or OH^- ions that are introduced into the solution. Since these ions control the value of pH, anything that prevents their concentration from changing will keep the pH stable. Distilled water, for example, has absolutely no buffering capacity since within it there is nothing that can react with incoming H_3O^+ or OH^- ions that are added to the solution. Distilled water should therefore have a pH of 7.0, it does not because we live in an environment where an acid can always be generated from the air. This acid – carbonic acid – is generated in water whenever it's put into contact with a carbon dioxide containing atmosphere. *This makes distilled water have a pH of around 5.6.*

To be able to calculate the pH we need to consider all the chemical equilibrium reactions that happen, these are summarized [here](#) and in the image above. We must consider that carbon dioxide will dissolve in water to always satisfy Henry's law, that dissolved carbon dioxide will be in equilibrium with carbonic acid, that carbonic acid can dissociate into a H_3O^+ ion and a bicarbonate ion and that a bicarbonate ion can further dissociate into an additional H_3O^+ ion and a carbonate ion. To solve all of this we must also consider that charge neutrality must be preserved, meaning that the sum of all molar charges of all positive ions must be equal to the molar charges of all negative ions. To carry out these calculations I routinely use the freely available [Maxima software](#). Below you can see the code I use to solve this system in Maxima (constants are taken from [here](#)):

```
[kw : 10^(-14.0), kh: 1.7*10^(-3.0), kc1: 2.5*10^(-4.0), kc2:  
4.69*10^(-11.0), co2: 1.32*10^-5];
```

```
log10(x) := log(x)/log(10) ;
```

```
pH(x) := float(-log10(x));
```

```
float(solve([h*oh=kw, h = 2*co3+hco3+oh, kh=h2co3/co2,  
kc1=(hco3*h)/h2co3, kc2=(co3*h)/hco3],[oh, co3, hco3, h2co3,
```

h]));

This is the solution obtained for the molar concentrations (rounded for clarity):

```
oh      = 4.21*10^-9
co3     = 4.68*10^-11
hco3    = 2.36*10^-6
h2co3   = 2.24*10^-8
h       = 2.37*10^-6
```

After executing this code you will get several different possible solutions, but the only one that interests us is the one where the H_3O^+ (h) concentration is a positive number (this solution is showed above). We can then use the pH function to calculate the value of pH for this H_3O^+ concentration, which gives us a value of 5.62, this matches the real measurement of a distilled water solution at 25C under a 387ppm carbon dioxide atmosphere. Note that the amount of none dissociated acid in solution is very small. Taken to mass, the concentration of carbonic acid is 0.00138 ppm. However the concentration of bicarbonate is significantly greater, at 3.6 times the concentration of undissociated carbonic acid. This explains why the pH drops so much, since a significant amount of the generated carbonic acid ends up dissociating and contributing H_3O^+ ions to the solution. This also shows you how little acid is needed to drop the pH of an unbuffered solution.

To create the buffer with the biggest possible strength we would need to add enough strong base to shift the pH to the point where the pH equals the pKa (which is just $-\text{Log}(\text{equilibrium constant})$) of the joint reactions created from the reaction of carbon dioxide with water to create carbonic acid and the subsequent dissociation of this acid into bicarbonate and H_3O^+ . This point is at 6.3 under atmospheric

conditions at 25C. This can be achieved with the code below:

```
[kw : 10^(-14.0), kh: 1.7*10^(-3.0), kc1: 2.5*10^(-4.0), kc2:
4.6910^(-11.0), co2: 1.32*10^-5, h:10^(-6.3)];
float(solve([hoh=kw, base+h = 2co3+hco3+oh, kh=h2co3/co2,
kc1=(hco3h)/h2co3, kc2=(co3h)/hco3],[oh, co3, hco3,
h2co3,base]));
```

This is the solution obtained for the molar concentrations(rounded for clarity):

```
oh    = 1.99*10^-8
co3   = 1.04*10^-9
hco3  = 1.11*10^-5
h2co3 = 2.24*10^-8
base  = 1.07*10^-5
```

The pH here is set to 6.3 and we can see that to get there we would need to add a base at a concentration of $1.07 \times 10^{-5.0}$. If this base was KOH this would imply adding it at a rate of 0.6 ppm. We can see how the pH changes as a function of adding base or acid from this point. If at this point we decided to double the addition of strong base we would get to 6.57, tripling it would take us to 6.73 and adding 10 times more base would take us to 7.25. The buffer is indeed resisting the increase in pH by basically drawing CO_2 from the air to react with the incoming base as base is added to the solution. *However you might notice that under equilibrium conditions the buffering capacity of this system is very low.* Just 6 ppm of a KOH equivalent strong base addition can strongly affect the pH – taking it from 5.6 to 7.25 – so how can the carbonic acid/bicarbonate buffer be effective at all in hydroponics?

The answer is in the first image in this post. The equilibrium reaction between carbonic acid and water plus carbon dioxide in water (k23/k32) is fundamentally slow. We can take advantage of this by generating larger amounts of carbonate species in solution through the use of exogenous carbonate or bicarbonate additions and then setting the pH at a lower value

to generate more carbonic acid, this acid will then take some significant time to reach equilibrium. This is the reason why using tap water with a significantly high alkalinity can provide a surprisingly stronger buffer than what would be expected at equilibrium and it also has some interesting consequences in the use of nutrient solutions.

Let's consider a case where there is no decomposition of carbonic acid – let's suppose it's extremely slow – and say we add 100 ppm of potassium carbonate into a solution and then set the pH back to 5.8 using phosphoric acid. In this case the predominant reactions in solution would be the dissociation of dihydrogen phosphate to hydrogen phosphate and H_3O^+ and the carbonic acid dissociation discussed before. In order to properly consider this case we must also introduce two additional equations, mainly the mass balance equations for the phosphate and carbonate species, since this time we are assuming no carbon dioxide is ever lost to the atmosphere. Note that I have changed the equilibrium constant for the carbonic acid reaction here to $10^{-6.3}$ where carbonic acid is now "apparent carbonic acid". You can see the equation system and solution below:

```
[kw : 10^(-14.0), kh: 1.7*10^(-3.0), kc1: 10^-6.3, co2:
1.32*10^-5, kp:10^-7.2, total_p: 1.7*7.2310^-4, total_c:
7.23*10^-4];
```

```
float(solve([h*oh=kw, total_c=hco3+h2co3, total_p=h2po4+hpo4,
2*total_c+h = hco3+oh+h2po4+2*hpo4, kc1=(h*co3h)/h2co3,
kp=(hpo4*h)/h2po4],[hco3, h2co3, h2po4, hpo4, h, oh]));
```

This is the solution obtained for the molar concentrations(rounded for clarity):

```
hco3    = 1.72*10^-4
h2co3   = 5.50*10^-4
h2po4   = 0.00118
hpo4    = 4.64*10^-5
h        = 1.60*10^-6
```

The final pH of this solution is very close to 5.8 and the concentration of P is 47.9 ppm with K at 38.10 ppm. Notice however that apparent carbonic acid has a concentration of 5.50×10^{-4} M, which implies that the system is not at equilibrium since this amount is significantly larger than what we would expect from Henry's law. If we reduce the concentration of carbonic acid to half then the pH will increase to 6.01, as we would expect from extracting an acid from the solution. The implication is that – with time – the pH of this solution is going to slowly increase, as carbonic acid decomposes and the solution reaches an equilibrium with the atmospheric carbon dioxide level. This is also why nutrient solutions that are prepared with tap water high in carbonates and then aerated will tend to show a rapid increase in pH – even if the solution is not fed to plants – as the reaching of equilibrium is accelerated by the agitation of the solution and the contact with air (that allows CO_2 in solution to escape).

As soon as the above solution is prepared it offers a substantially superior buffering capacity when compared with a solution containing only phosphates. This is why water with high alkalinity tends to provide better pH stability in drain to waste type systems when compared with solutions prepared with RO water. This water contains a significant amount of carbonates that are turned into carbonic acid and bicarbonate as soon as the pH is lowered to the pH range used in hydroponics. As long as the solution is used quicker than the carbonic acid decomposes, there will be a substantial increase in pH stability.

If you are using RO water or water with low alkalinity to prepare your solutions you can obtain a similar effect by adding 100-200 ppm of potassium carbonate before you start preparing the nutrient solution, you can similarly use bicarbonate but I would recommend using potassium carbonate, as it is cheaper. It would also be advisable to use the

solution as fast as possible, since time will cause the solution to reach equilibrium and the pH to increase. This effect will take much longer if the CO₂ concentration is higher – which is true for setups that use enriched CO₂ – or if the temperature is lower, which increases the solubility of CO₂.

Hydroponics nutrients and microgreens

One of the most important goals in microgreens is to maximize the amount of weight gained by shoots from seed to harvest. Since the entire upper body of the plant is harvested and plants are sold by weight, maximizing the weight gain is vital in order to obtain the highest possible margins in a crop cycle. Hydroponically cultured microgreens offer the grower an unprecedented control over the microgreens' nutrition, with the ability to tightly control nutritional parameters in order to maximize this weight. In this article we are going to take a look into the scientific literature surrounding microgreens and what we know about maximizing their yield and quality using nutrient solutions. I will use the table below to reference different articles in the literature.

Number	Species	Studied	Link
1	Broccoli	FlograGro, sterile, compost	https://www.frontiersin.org/articles/10.3389/fnut.2017.00007/full
2	Purple Cabbage	Nutrient sol conc	https://www.scielo.br/scielo.php?pid=S1983-21252019000400976&script=sci_arttext&tlng=en
3	Table Beet	Calcium Nitrate	https://www.tandfonline.com/doi/abs/10.1080/19315261003648241
4	Radish	Calcium Chloride	https://bearworks.missouristate.edu/theses/3328/
5	Basil	Sodium Selenate	https://onlinelibrary.wiley.com/doi/abs/10.1002/jsfa.9826

Published articles talking about hydroponic nutrients and

microgreen yield or quality

Despite the overwhelming growth in the microgreen industry during the past 10 years, the amount of research looking into microgreen nutrition has been surprisingly limited, with only a handful of papers looking at the relationship between nutrition and yields or quality. Paper one contains a comparison between microgreens grown in either compost, sterile water or a solution using a 0.4% FloraGro Advanced Nutrient solution (4mL/L). The results show clear weight benefits from using hydroponic nutrients, with the weight being markedly higher (mean of 24.64g vs 21.01g) between the sterile and hydroponic treatments. However the concentration of different minerals was actually lowest in the plants using a hydroponic nutrient.

Table 3: Shoot fresh weight per plant and per population of 'Early Wonder Tall Crop' table beet at 15 days after planting in response to seed ball and fertilizer treatments.

Seed treatment (ST)	Fertilization treatment (FT) ^a	Shoot fresh weight (g·m ⁻²)	Shoot fresh weight (mg/shoot)
Nontreated	Check	2705h	166e ^b
	CN	4207f	268d
	SF	4676e	268d
	0.5 CN + 0.5 SF	4676e	284cd
	CN + SF	5469cd	299cd
Pregerminated ^c	Check	3391g	298cd
	CN	5087de	362b
	SF	5649c	306c
	0.5 CN + 0.5 SF	6294b	362b
	CN + SF	6937a	415a
Interaction LSD _{0.05}		444	36
Significance			
ST		***	***
FT		***	***
ST × FT		*	**

***, **Significant at $P = 0.05$, $P = 0.01$, or $P = 0.001$, respectively.

^aCheck = no additional fertilizer added to the peat-lite; CN = preplant addition of solid $\text{Ca}(\text{NO}_3)_2$ at $2000 \text{ mg}\cdot\text{L}^{-1}$ of N ($150 \text{ mL}\cdot\text{L}^{-1}$ of peat-lite); SF = daily application of $150 \text{ mg}\cdot\text{L}^{-1}$ of N solution fertilizer from 21-5-20; 0.5 = one-half rate.

^bMeans within a column followed by the same letter are not significantly different by LSD_{0.05}.

^cPregerminated = seed ball incubation in fine (grade 5) vermiculite with 150% water for 5 days at 20°C.

Table taken from article number three

Papers three and four look at different forms of Ca nutrition – either Ca chloride or Ca nitrate – and different ways to apply this treatment to see if it makes a difference in microgreen production. Paper three, shows a statistically significant gain in weight when using calcium nitrate, either applied into the media pre-cultivation or applied within a nutrient solution. The best results were found when both treatments were carried out and represented an increase of

more than double in terms of weight over the control. The fact that paper four fails to show a consistent increase in yields using Ca chloride, suggests that this has to do mainly with the nutritional contribution of the nitrate and not the calcium ions.

Paper two is rather interesting, as it looks into different nutrient solution strengths (either 0, 50 or 100%) using a solution published for hydroponic forage. The results – in the table below – clearly show that there is a strong weight gain as the nutrient solution concentration increases, again showing that at a full strength solution there is an expected increase of more than 2x in the final weight. However this comes – in agreement with paper one – at the potential expense of nutritional value. The paper shows a significant decrease in carotenoid concentration when nutrient solution strength increases, which the paper hypothesis is caused by high nutrient concentrations slowing down plant metabolism. This hypothesis is however hard to reconcile with the larger and heavier plants.

Table 2 Effect of cultivation substrate and nutrient solution concentration on shoot fresh matter yield (SFMY) and shoot dry matter yield (SDMY), shoot height at harvest (SHH), and total soluble solids (TSS) content of purple cabbage microgreens (*Brassica oleracea* var. *capitata* f. *rubra*) in a recirculating system. Porto Alegre, Brazil, 2018.

Factors	Trataments	SFMY	SDMY	SHH (cm)	TSS (°brix)
		(g m ⁻²)			
Substratos	S1 (CSC [®] Vermiculite)	1829.52 ^{ns}	74.01 ^{ns}	6.86 ^{ns}	3.62 ^{ns}
	S2 (Beifu [®] S10)	1761.30	79.21	6.89	3.64
	S3 (Carolina Soil [®] seedling)	1795.73	75.70	6.83	3.73
	S4 (Carolina Soil [®] organic)	1793.57	81.10	7.19	3.82
Concentration Nutritive Solution **	C1 (0%)	1111.31 c [*]	64.34 c	5.00 c	5.03 a
	C2 (50%)	1933.16 b	78.62 b	7.36 b	3.37 b
	C3 (100%)	2340.62 a	89.59 a	8.48 a	2.72 c
	Mean	1795.03	77.52	6.94	3.70
	CV (%)	16.34	11.29	6.83	14.45

^{ns}not significant by the Tukey's test at 5% probability;

^{*} means followed by the same letter in the columns are not different by the Tukey's test at 5% probability.

^{**} initial electrical conductivity (ECi) established for the three evaluated nutrient concentrations (0%, 50%, and 100%) in the nutritive solution: C1 = 0.0; C2 = 1.20, and C3 = 2.0 dS m⁻¹, respectively.

Table taken from article number two

Article five is also an interesting example of the use of microgreens to carry out antioxidant supplementation. Sodium selenate was used to prepare a solution to treat basil seeds

and the resulting microgreens were found to be fortified with selenium. This might be an interesting way to incorporate mineral micro nutrients into microgreens and therefore increase their presence within our diet. However there is also the potential to hyperaccumulate these nutrients, so experiments of this kind should not be done with adequate care and lab analysis to ensure proper doses of these micro nutrients.

From all of the above it seems quite clear that the research of hydroponic nutrients in microgreen production is in its very early infancy. So far only a handful of research papers have been published on the subject and the conclusions so far seem to be that hydroponic nutrient solutions – in a couple of different forms – tend to significantly increase microgreen production weights. However it is also clear that there is a strong interaction with the nutritional value of the microgreens and using nutrients can in fact lead to decreases in the nutritional value, despite the significant weight gain from the process.

The echoes of the above can be seen in a wide variety of anecdotal experiences on youtube channels and forums. Growers running side by side experiments seem to have found the same phenomena (see [this video](#) for an example), where adding nutrients increases yields significantly but at the expense of some of the flavor – and potentially nutritional – characteristics of the microgreens. Some growers have therefore chosen to avoid nutrients – to preserve flavor qualities – while others have chosen to use nutrients because of the increases in marketable appearance and yield.

There is a lot of research to be done on the subject. It would certainly be interesting to find out if we could somehow have the best of both worlds.

A guide to different pH down options in hydroponics

The control of pH in hydroponic nutrient solutions is important. Plants will tend to increase the pH of solutions in most cases – as nitrate uptake tends to dominate over the uptake of other ions – so most growers will tend to use pH down much more than they use pH up. While most growers prefer to use concentrated strong acids, there are a wide variety of different choices available that can achieve different outcomes at different cost levels. In this post I want to talk about different pH down options in hydroponics, along with some of their advantages and disadvantages.



Hydrangeas change color as a response to different pH values in soil

The first group of pH down chemicals are strong acids. These are technically acids with very low pKa values, meaning they react instantly with water to generate at least one mole of hydronium for each mole of added acid. They offer the strongest ability to drop pH per unit of volume, which makes them more cost effective. However the fact that they often need to be diluted to make the pH addition process practical –

because of how much the concentrated forms can change pH – can make their use more difficult than other forms of pH down. These are the most common options:

Phosphoric acid (from 20 to 85% pure): This acid doubles as a plant nutrient, meaning plants will be affected by the phosphorus added. It is commonly used in food – so food grade phosphoric acid can be bought cheaply – it also has additional deprotonations with strong buffering at a pH value of 7.2 with buffering capacity against bases getting stronger as the pH goes down all the way to 6.2. This is the most commonly used acid by hydroponic growers.

Sulfuric acid (from 20 to 98% pure): This acid is commonly used in car batteries and offers the largest pH dropping ability per unit of volume among all the strong acids. It is however important to use food grade sulfuric acid in hydroponics as normal battery acid can include some metallic impurities – from the fabrication process of sulfuric acid – that might negatively affect a hydroponic crop. Food grade sulfuric acid is safe to use in hydroponics. A big advantage is that plants are quite insensitive to sulfate ions – the nutrient provided by sulfuric acid – so adding sulfuric acid does not really affect the nutrient profile being fed to the plants. Note however that most battery acid products in developed countries are also ok, as the quality of these acids demands the metallic impurities (more commonly iron) to be quite low. If in doubt, you can do a lab test of the sulfuric acid to see if any impurities are present.

Nitric acid (from 30-72% pure): This acid also provides nitrate ions to plants, so it also contributes to a solution's nutrient profile. It is however more expensive than both phosphoric and sulfuric acids and more heavily regulated due to its potential use in the fabrication of explosives. The acid itself is also a strong oxidant, so storage and spillage problems are significantly worse than with phosphoric and sulfuric acid. Although this acid can be used in hydroponics,

it is generally not used by most growers due to the above issues.

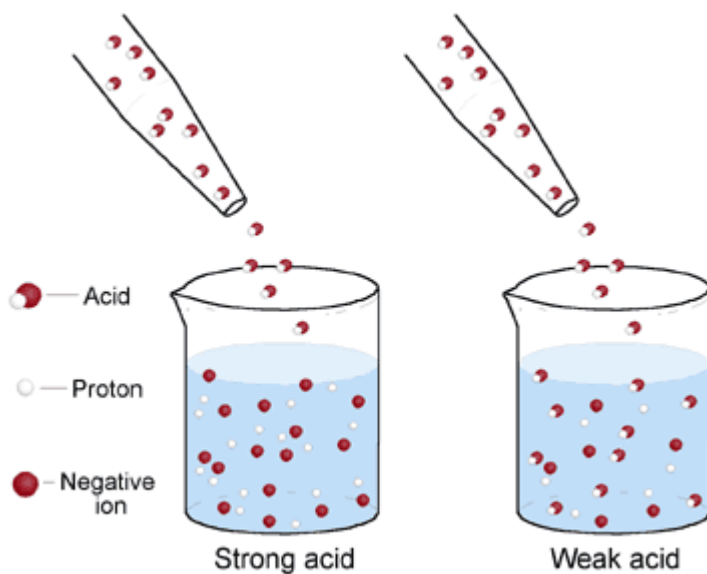


Diagram showing the dissociation of a strong vs a weak acid

The second group of pH down chemicals are weak acids. These are acids that do not generate at least one mole of hydronium ions per mole of acid when put in solution, but do provide a pH down effect as some hydronium ions are generated. This means that larger additions will be needed to cause the same effect but at the same time their handling is usually much safer than for strong acids. Here are some options that could be used as a pH down.

Common food grade organic acids (citric acid, acetic acid, etc): Organic acids are a very low cost way to lower the pH of a hydroponic solution as many of these are available off the shelf in super markets in food grade qualities. The main issue with organic acids – which anyone who has used them has probably experimented – is that the effect of the acids does not seem to hold (pH goes up quickly after the acid is added and the solution comes into contact with plants). This is actually caused by the fact that plants and microbes can actually use the conjugated bases of these ions nutritionally, causing an increase in pH when they do so. The initial addition of say, citric acid, will drop the pH – generating citrate ions in the process – these will then be absorbed by

microbes and plants, increasing the pH again rapidly. *The use of these acids is therefore not recommended in hydroponics.*

Monopotassium phosphate (MKP): This salt contains the first conjugate base of phosphoric acid and is therefore way less acidic than it's full on acid partner. Since it's a solid its addition is way easier to control compared to the acid and it can also be handled safely with minimal precautions. It provides both potassium and phosphorous to a solution – both important nutrients – and therefore needs to be used carefully when used as a pH down agent (as it significantly affects the nutrient profile of the solution). Since it adds both a cation that helps counter pH increases by plants and phosphate species it provides a double buffering effect against future pH increases. It is a very common ingredients of commercial pH down solutions for this reason.

Monoammonium phosphate (MAP): Similar to the above, except for the fact that this salt adds nitrogen as ammonium, which is a nitrogen form plants are very sensitive to. Plants will uptake ammonium preferentially over any other cation, so MAP provides a very strong buffering effect against nitrate absorption, with potential problems if too much is used (although this depends on the plant species being grown). When MAP is used as a pH down its addition therefore needs to be carefully controlled in order to avoid excess usage. Due to the presence of this powerful ammonium buffer, MAP is generally very effective at preventing future increases in pH, although this might be at the expense of yields or quality depending on the crop.

Potassium bisulfate: This salt contains the first conjugate base of sulfuric acid and is therefore a powerful tool to decrease the pH of a solution. The resulting sulfate ions provide no chemical buffering effect, so the only buffering effect in terms of plant absorption comes from the addition of potassium ions, which can help mitigate nitrate absorption. This salt is also considerably expensive compared with the two

above – which are commonly used fertilizers – and is therefore seldom used in hydroponics.

Which is the best pH down solution? It depends on the characteristics of the growing system. Generally a pH down solution needs to be easy to administer, cheap and provide some increase in buffering capacity overtime – to make additions less frequent – so the pH down product or combination of products that best fits this bill will depend on which of the above characteristics is more important for each particular user.

People who use drain-to-waste systems usually go for stronger acids, since they only adjust pH once before watering and then forget about the solution. This means that additional buffering capacity in the solution is probably not going to be very important and cost is likely the most important driving factor. If injectors are used then the strong acids are often diluted to the concentration that makes the most sense for them and most commonly either phosphoric or sulfuric acids are used.

For growers in recirculating systems options that adjust pH with some added buffering capacity are often preferred, because the same solution is constantly subjected to interactions with the plants. In this case it's usually preferred to create a mixture of strong and weak buffering agents so that both quick decreases in pH and some increased protection from further increases can be given to the solution. In automated control systems using something like a concentrated MKP solution is preferable over any sort of solution containing phosphoric acid, as issues from control failures are less likely to be catastrophic.

Nutrient solution estimates in Hydrobuddy

People who use Hydrobuddy can be confused by its conductivity estimates, especially because its values can often mismatch the readings of conductivity meters in real life. This confusion can stem from a lack of understanding of how these values are calculated and the approximations and assumptions that are made in the process. In this post I want to talk about theoretically calculating conductivity, what the meters read and why Hydrobuddy's estimations can deviate from actual measurements.

HydroBuddy v1.62 - Programmed and Designed by Dr. Daniel Fernandez Ph.D at <http://scienceinhydroponics.com>

Welcome Main Page Results About

Substance Name	Formula	Mass (g) [Edit to fine-tune]	Preparation Cost
Yara Calcium Nitrate	Yara_Ca(NO3)2	1028.04	102.8
Potassium Nitrate	KNO3	491.68	49.2
Potassium Monobasic Phosphate	KH2PO4	148.47	14.8
Magnesium Sulfate (Heptahydrate)	MgSO4.7H2O	486.815	48.7
Boric Acid	H3BO3	2.86	0.3
Iron EDTA	Fe(EDTA)	19.231	1.9
Copper Sulfate (pentahydrate)	CuSO4.5H2O	0.079	0
Zinc Sulfate (Dihydrate)	ZnSO4.2H2O	0.151	0
Sodium Molybdate (Dihydrate)	Na2MoO4.2H2O	0.025	0
Manganese Sulfate (Monohydrate)	MnSO4.H2O	1.538	0.2

Element	Result (ppm)	Gross Error	Instrumental Error
N (NO3-)	216.165	2.9%	+/- 0%
K	232.791	-0.9%	+/- 0%
P	33.789	9%	+/- 0%
Mg	48	0%	+/- 0%
Ca	195.328	-2.3%	+/- 0%
S	63.661	-0.5%	+/- 0%
Fe	2.5	0%	+/- 0.1%
Zn	0.05	0%	+/- 6.6%
B	0.5	0%	+/- 0.4%
Cu	0.02	0%	+/- 12.7%
Mo	0.01	0%	+/- 39.7%
Na	0.005	0%	+/- 0%
Si	0	0%	+/- 0%
Cl	0	0%	+/- 0%
Mn	0.5	0%	+/- 0.7%
N (NH4+)	11.308	0%	+/- 0%

Total Cost is 217.9

Values calculated for the preparation of 1000 liters

Predicted EC Value: EC=1.8 mS/cm

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

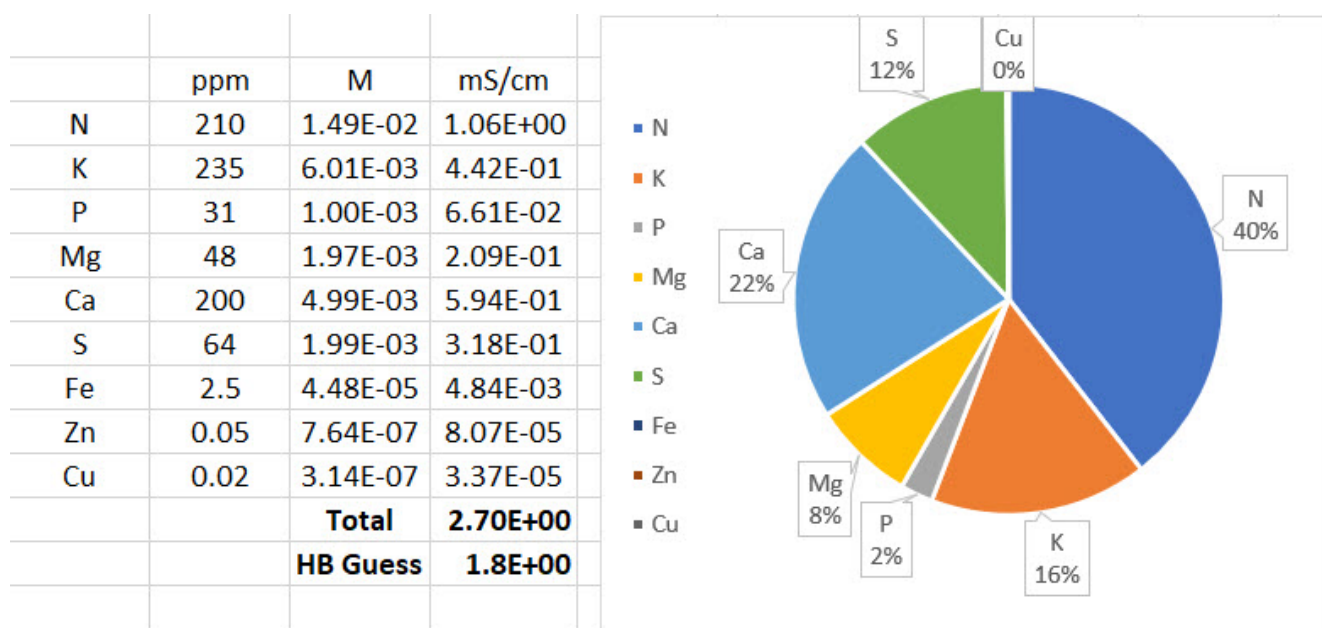
Export To Csv

Standard Hoagland solution calculation using HydroBuddy with a set of basic chemicals.

The images above show the use of HydroBuddy for the calculation of a standard Hoagland solution for a 1000L

reservoir. The Hoagland solution's recipe is expressed as a series of elemental concentrations, all of them in parts per million (ppm) units. The results show that the final conductivity of this solution should be 1.8 mS/cm but in reality the conductivity of a freshly prepared full strength Hoagland solution will be closed to 2.5mS/cm. You will notice that HydroBuddy failed to properly calculate this value by an important margin, missing the mark by almost 30%. But how does HydroBuddy calculate this value in the first place?

Conductivity cannot be calculated by using the amount of dissolved solids in terms of mass because charges are transported per ion and not per gram of substance. To perform a conductivity calculation we first need to convert our elemental values to molar quantities and then associate these values with the limiting molar conductivity of each ion, because each ion can transport charge differently (you can find the values HydroBuddy uses in the table available in [this article](#)). This basically means we're finding out how many ions we have of each kind and multiplying that amount by the amount each ion can usually transport if it were by itself in solution. The sum is the first estimate in the calculation of conductivity.



Conductivity calculations carried out by HydroBuddy, also

showing conductivity contributions per ion. This is done by converting ppm quantities to moles, then multiplying by limiting molar conductivity values here.

The image above shows the result of these calculations for an example with a perfectly prepared Hoagland solution. You can see that the estimate from limiting molar conductivity is initially 2.7 ms/cm – much closer to the expected 2.5 mS/cm – but then HydroBuddy makes an additional adjustment that lowers this down to 1.8 mS/cm. This is done because limiting molar conductivity values make the assumption of infinite dilution – what the ion conducts if it were all by itself in solution – but in reality the presence of other ions can decrease the actual conductivity things have in solution. HydroBuddy accounts for this very bluntly, by multiplying the result by 0.66, in effect assuming that the measured value of conductivity will be 66% of the value calculated from the limiting molar conductivity values. This is of course wrong in many cases, because the reduction in activity due to the presence of other ions is not as strong. However it can also be correct in many cases, primarily depending on the substances that are used to prepare the formulations and the ratios between the different nutrients.

In my experience HydroBuddy tends to heavily underestimate the conductivity of solutions that receive most of their conductivity from nitrates, as this example, but it tends to do much better when there are large contributions from sulfate ions. When I first coded HydroBuddy all my experiments were being done with much more sulfate heavy solutions, so the correction parameter value I ended up using for the program ended up being a bad compromise for solutions that deviated significantly from this composition. With enough data it might be possible to come up with a more advanced solution to conductivity estimations in the future that can adjust for non-linear relationships in the conductivity and activity relationships of different ions in solution.

If your measured conductivity deviates from the conductivity calculated in HydroBuddy you should not worry about it, as HydroBuddy's values is meant to be only a rough estimate to give you an idea of what the conductivity might be like but, because of its simplicity, cannot provide a more accurate value at the moment. The most important thing is to ensure that all the salts, weights and volumes were adequately measured in order to arrive at the desired solution.

Sugars in hydroponic nutrient solutions

Carbohydrates are an integral part of plants. They produce them from carbon dioxide, requiring no additional external carbon inputs for the process. However, since plants can absorb molecules through their leaves and roots, it is perhaps natural to wonder whether they could also get carbohydrates through the roots and avoid some of the stress they go through in order to produce these molecules from scratch. If plants can uptake sugar and we feed them sugars then will we get fruits with more sugars and bigger plants? It's an interesting question that I will try to answer within this post, looking at the potential use of simple sugars within hydroponic nutrient solutions.



Simple table sucrose

Although the above idea sounds straightforward, it hardly has any interest in the scientific literature or the commercial hydroponic industry. You will find no significant number of research papers studying the use of sugars – simple or complex – in hydroponic nutrient solutions and very few studies looking at sugar uptake and the interactions of *in-vitro* plant tissue with simple sugars. *This lack of interest and use is no accident, it comes from an already established understanding of plant physiology and the realization that it is not cost effective, useful or needed to add sugars to nutrient solutions.*

Let us start with what we know about the subject. We know that plants exude very significant amount of sugars through their root systems and we also know that they can re-uptake some of these sugars through their roots ([see here](#)). From this paper it seems that maize plants could uptake up to 10% of the sugars they exude back into their root systems, which implies that some exogenous sugar application could find its way into plant roots. Even worse, transporting this sugar up to the shoots is extremely inefficient, with only 0.6% of the sugar making it up the plant. This tells us that most of the sugar is wasted in terms of plant usage, a large majority never makes it into the plant and the little amount that makes it actually never goes up the plant. *Plants are simply not built to transport sugars in this manner, they evolved to transport*

sugars down to roots and to fruits.

But what about the roots? Given that the plant tissue that would be in direct contact with the sugar is the roots, it is logical to think about positive effects affecting them primarily. We have some studies about the influence of sugar solutions in seedlings (like [this one](#)) which does show that sugars can stimulate the growth of new root tissue in very small plants. However in large plants most of the sugar content in the roots will come from transport from the higher parts of the plant and the local sugar concentration will be low. Seedlings can likely benefit from sugars in the roots because leaves are producing very little at this time but larger plants are unlikely to benefit from this effect.

There is however one effect that sugars have that is very clear, they feed the rhizosphere around the plant's roots. Although plants try to care about this themselves – by exuding an important amount of sugars and organic acids – an exogenous sugar addition would most likely boost the amount of microbes around plant roots (both good and bad ones). The profile of sugars and acids exuded by plants is most likely tuned by evolution to match the microbes that are most beneficial to it and an unintended and negative effect of sugars is to boost all microbe populations at the same time, regardless of whether they are good or bad for the plant. This also increases oxygen demand around roots – because aerobic microbes will want to oxidize these sugars – reducing the amount of oxygen available to plant roots. For this reason, any application of a sugar to a nutrient solution requires the inoculation of the desired microbes beforehand, to ensure no bad actors take hold. It also requires the use of a media with very high aeration, to prevent problems caused by oxygen deprivation.

Sadly there aren't any peer reviewed papers – at least that I could find – investigating the effect of exogenous sugars on the yields of any plant specie in a hydroponic environment.

Given our understanding of plant physiology, any positive effects related with anecdotal use of sugars are most likely related with positive effects in the rhizosphere that are linked with improved production of substances that elicit plant growth in the root zone by favorable microbes. This is mainly because it is already well established that transport of sugars within plants from the roots to the shoots is incredibly inefficient, so any contribution of the roots to sugar uptake will be completely dwarfed by the actual production of sugars from carbon dioxide in the upper parts of the plant. It is not surprising that no one seems to want to do a peer reviewed study of a phenomenon whose outcome is already largely predictable from the accepted scientific literature.

If you're interested in the use of sugars in hydroponics, it is probably more fruitful to focus on microbe inoculations instead. Sugars themselves are bound to provide no benefit if they are not coupled with a proper microbe population and, even then, you might actually have all the benefits without any sugar applications as the microbes can be selected and fed by plant root exudates themselves in mature plants although sugars might provide some benefits in jump starting these populations, particularly in younger plants. Also, bear in mind that there is also a very high risk of stimulating bad microbes with the use of sugars, especially if oxygenation is not very high.

Maximizing essential oil

yields: A look into nutrient concentrations

Essential oils are the main reason why several plant species are currently cultivated. These oils have a wide variety of uses either in the food industry or as precursors to more complex products in the chemical industry. Modifying nutrient solutions to maximize oil yields in hydroponic setups is therefore an important task. However, there are sadly no clear guidelines about how this can be achieved. In today's post I wanted to create a small literature review of different research papers that have been published around the modification of nutrient solutions to maximize essential oil production and see if we can draw some conclusions that should apply to plants that produce them.



The variety of plants that produce essential oils is nothing but amazing. From plants where mainly the leaves are harvested – such as mint and basil – to plants where the flowers are used – such as roses – to plants where the seeds are used, like coriander. The wide variety of oil sources and plant species implies that the universe of potential research is immense, with every potential nutrient modification in every plant giving a potentially different optimal measurement. However, plants share some important characteristics – like

photosynthesis and root absorption of nutrients – plus essential oils within different plants can share components produced using similar chemical pathways. For this reason, a look into the research universe of nutrient solution optimization for essential oil production is likely to serve as a base to guide us in the optimization of a solution for a particular plant.

Plant	Optimal (ppm)	Link to reference
Mint	195-225 N , 178-218 K	https://www.actahort.org/books/853/853_18.htm
Sweet Basil	180 Ca	https://www.cabdirect.org/cabdirect/abstract/20013048426
Costmary	200 N, 200 K	https://pubag.nal.usda.gov/catalog/732179
Mint	<= 276 K	http://www.scielo.br/scielo.php?pid=s0103-84782007000400006&script=sci_arttext
Chrysanthemum	159 Ca	https://pdfs.semanticscholar.org/13ea/999605458e65d9023dadababca48464a5fa70.pdf
Chrysanthemum	43 N (NH4)	https://tinyurl.com/vqupwvf
Lavender	300 K	https://scielo.conicyt.cl/scielo.php?pid=S0718-95162017005000023&script=sci_arttext&tlng=en
Rose Geranium	207 K	http://ir.cut.ac.za/handle/11462/189
Rose Geranium	110 S, >= 68 P	https://www.tandfonline.com/doi/full/10.1080/02571862.2012.744108
Spearmint	200 N	https://www.sciencedirect.com/science/article/abs/pii/S2214786117300633
Lavender	200 N, 50 P	https://www.sciencedirect.com/science/article/abs/pii/S0926669015306567
Mint	414 K	https://sistemas.uft.edu.br/periodicos/index.php/JBB/article/view/601
Spearmint	50-70 P	https://www.sciencedirect.com/science/article/pii/S0308814618317862
Marjoram	>= 36 Mg	https://www.actahort.org/books/548/548_57.htm
Salvia	150 N	https://pubs.acs.org/doi/abs/10.1021/jf030308k
Dill	300 N	https://www.actahort.org/books/936/936_22.htm

Summary of different papers addressing essential oil yield optimization in hydroponic setups by varying one or several nutrient concentration values.

In the table above I summarize the research I found concerning the optimization of some mineral nutrient in the hydroponic production of a plant, specifically to maximize the essential oil yield. All of these studies optimized the nutrient within a given range and a >= or <= sign is used whenever the optimal value found is at the top or bottom of the range respectively. When more than one nutrient was optimized in the paper, I give you the values for both nutrients so that you can glimpse the optimal. Whenever the researchers suggest an optimal range

instead of a value within their research this is also included as a range. I tried to find papers representing all macro nutrients but studies optimizing some elements were hard to find (Mg for example). Although I tried to include as many species as possible some species are just more commonly studied, as they are commercially more relevant (like mint and basil).

From these research results we can immediately see some clear trends. From all the studies there is no result where optimal total nitrogen concentration is below 150 ppm and 3 out of the 4 studies I found, agree that the optimal N concentration is at 200 ppm. In the case of K all studies agree that K should be at least 200 ppm, but I did find a study on mint that got a value of 414 ppm, far larger than the value found in other studies for the same specie. This is not an uncommon discrepancy in hydroponics – optimal yields being mixed in a wide range above 200 ppm of K – which can be caused by other issues that can affect K absorption, such as the concentration of other important cations (like Ca and Mg) in the studies.

I was only able to find two studies that focused on Ca and both agree about optimal values between 150 and 180 ppm, although they address two completely different plant species (basil and chrysanthemum). In the case of Mg I found only one study and its conclusion was mainly that you want to have more than 36 ppm of Mg in solution. This is not surprising as Mg is rarely a growth limiting element in hydroponics and usually growth will not be limited to it unless its supply is very low compared to the supply of other nutrients (which is very rarely the case).

In the case of P, it's not surprising that most papers that addressed this nutrient studied plants where the essential oils are mainly in the flowers (rose and lavender), as phosphorous is a nutrient commonly associated with flowering. In the case of rose the best value in the study was sadly the upper limit and in the case of lavender the optimal value

reached was 50 ppm. In this case we can therefore probably only say that both studies share having an optimal result of ≥ 50 ppm but it's hard to provide an upper bound for this. A study addressing P in spearmint also finds optimal P to be within exactly this range at 50-70 ppm.

Element	ppm
N	200
P	60
K	200
Ca	160
Mg	45

A base "guess" formulation for a plant producing essential oils

With these results in mind, we can sketch a base solution for a plant where essential oil production is being targeted.. An obvious guess would be to start with a solution with the concentration profile showed above. In this case we target N and K at 200 with an N:K ratio of 1 and we keep Ca at 160, making the K:Ca 1.25 (which is surprisingly close to the optimal value discussed in my [Ca post](#)). We leave P at 60 – the middle of the 50-70 range – and we keep Mg at 45, which is > 38 and is a value commonly used in regular hydroponic solutions. **The above will certainly not be the best solution for any single plant *a priori*, but it might provide a good base to start optimizing from if the objective is essential oil production.**

The media exchange solution

test: A better measurement of media effects in hydroponics

In the traditional hydroponic paradigm we want media to be as chemically inert as possible. The ideal media in this view would absorb no nutrients, give off no nutrients and would not decompose or react with the nutrient solution in any way. However none of the commonly available media sources comply with these properties, reason why we must be vigilant and properly adjust the media we use to fit the needs of our hydroponic setup. In this article I am going to talk about the idea of using a direct comparison test of the nutrient solution against the media, to understand the effect the media will have when exposed to the target nutrients and how this can help us adjust our solutions to better play with the selected growing medium.



Different types of growing media

First, let us understand how the media interacts with a hydroponic solution. The media can do all of the following things:

- **Dissolve into the solution** (this is what happens if your

media is something like sand or limestone). In this case the media is chemically reacting with the nutrient solution, therefore media is being irreversibly lost in the process. This can happen very fast, with something like limestone, or very slowly, with something like sand.

- **React and take something away from the solution.** In this case the media can use ions within the solution to perform reactions that create new substances that are insoluble. For example if you have media containing large amounts of rock phosphate this phosphate can cause the precipitation of heavy metal phosphates.
- **Release ions in exchangeable locations into the media.** This is different than dissolving because the media is not getting destroyed in the process but it is emptying “storage sites” that contain some ions that prefer the solution instead of these sites. This process is fundamentally reversible and – under the proper conditions – these sites could be replenished with the same or different ions.
- **Take ions into exchangeable locations in the media.** This is the opposite of the process above. In this case the media will receive some ions into “storage sites” because these ions prefer the media to the hydroponic solution. The solution will therefore be depleted of these ions because they are being stored within the media.

Of most interest to us are the third and fourth points above, this is generally understood as the “exchange capacity” of the media. This determines how many and which nutrients the media can store. Different media can have storage sites with different affinities and in hydroponic setups we generally want to aim for the minimum energy state of these storage sites as they relate to our nutrient solution. Media that is already in equilibrium with the nutrient solution will tend not to change it while media that is far away from equilibrium

with the solution will change it strongly towards the equilibrium point.

Think about coco coir, a commonly used media in hydroponics that can have a wide variety of different ion exchange capacity values and a lot of different ions initially in its “storage sites” due to the differences in sourcing materials and treatments done by different companies. Coco coir initially contains high amounts of potassium and sodium ions, but some companies treat it with Ca nitrate, which changes all these “storage sites” to contain Ca instead. These two sources of coco would interact very differently with our nutrient solution. In the first case the coir would exchange a lot of its potassium for Ca and Mg ions in solution – because these ions have higher affinity for the “storage sites” – while in the second case a little Ca would be exchanged for other ions (because all ions are in equilibrium with all the storage sites). The changes to the solution are very different and totally different approaches in nutrient composition changes are required.

Traditional soil tests could provide some answer to us, they would definitely show the ions that could be exchanged to be different in both cases. But they tell us little about the equilibrium position of the media against our target nutrient solution. To make things more realistic we can actually do a test where we pass our actual nutrient solution through a column of media that is exactly what we’re going to run it through in real life (with no plants of course). We then collect the input and output solution and run lab analysis of both of these solutions. **We can then compare the results and see how much the media is actually changing the composition of our input solution and we can then make some decision to adjust.** Such a test would proceed as follows:

1. Prepare the strongest final solution that will be used in the growing process. (for example the solution that is used at the peak of fruit generation in a tomato

crop)

2. Take a sample of this starting solution to send for chemical analysis.
3. Pack a burette with a column of media as high as the containers the plants will be in.
4. Fill the burette with the nutrient solution.
5. Run as much solution as required to collect a sample of equal volume to the first one.
6. Send both samples for analysis.

The difference in nutrients between both solution will show us what we should initially be doing to maintain a consistent composition of the nutrient solution, given the interaction with the media. If the interaction is too strong it can also tell us that we shouldn't be using this media without previously treating it to ensure the imbalances do not happen. For example media like biochar can have an extremely high affinity for metal chelates and nitrogen compounds, if we ran our solution through the media and it turns out that it soaked up almost all of our iron and ammonium, we wouldn't want to just add more nitrate and heavy metals but we would like to pretreat the media with a concentrated solution and then repeat the test to ensure that the media is at a level of activity that we can correct for.

A given media source that is acceptable should not strongly affect the nutrient solution. Any media that does this in the media exchange test requires correction so that the ability to take elements from the nutrient solution is reduced. The test will tell you exactly what the media is finding most appetizing and the treatment options will then be substantially easier to plan. A coco coir that shows it soaks up almost all the Ca will need to be treated with a Ca nitrate solution and a biochar that absorbs a lot of ammonium will need to be treated with an ammonium sulfate solution. These are some cheap pretreatments that will save a lot of heartache within a hydroponic setup and will make the ongoing growing

process substantially easier to manage.

This is one of the simplest and cheapest tests that can be done to address media effects. However it is by no means comprehensive in that it does not show us other important media properties that might be crucial for selection. It is important to consider that this test gives us only a glimpse of the chemical properties and the interactions with the actual nutrient solution we intend to use. Other media specific analysis and more complicated media run-off tests can be necessary to address the full extent of the interactions through an entire crop cycle.

Five things you should know when mixing your own hydroponic liquid nutrients

Many hydroponic growers – especially large scale ones – can benefit greatly from mixing their own custom nutrients. Not only can this save money in the thousands of dollars per month but it can also give you an unprecedented degree of control when compared with store-bought nutrients. On today's post I am going to write about five important things you should know when mixing your own nutrients so you can avoid many common problems that can arise when you start preparing your own stock solutions.



More concentrated solutions are not always better. When you prepare a concentrated liquid you would usually want to go with the highest possible concentration factor so that you can prepare as much final nutrient solution as possible with as little stock solution as possible. However trying to get into higher concentration factors (1:400-1:500) can cause important issues due to the solubility of the salts used and the temperatures the stock solution will be exposed to. It can also cause high inaccuracies with variable injector setups since the dilutions will be much smaller. For starters go with a 1:100 concentration factor and only start going higher when you get more experience. If you're using injectors I would generally avoid a range higher than 1:250 unless you do more extensive calibration procedures with your injectors.

Impurities can cause important problems. Some salts can come with significant levels of impurities – sometimes mainly additives – that can cause substantial issues when preparing your nutrient solutions. Lower quality grade salts – mainly those used for soil fertilization or those that are OMRI listed and come straight from mining with no refining – can generate problems within your mixing process. These problems range from insoluble left-overs in tanks to toxic amounts of

some micro elements. To ensure you get the best possible results use greenhouse grade fertilizer salts and try to avoid sources of salts that are OMRI listed. Synthetic sources that have been heavily purified are your best bet in ensuring the best possible results.

Use slightly acidic deionized water to prepare the solutions. Most water sources in Europe and the US are very heavy in carbonates and therefore inappropriate for the preparation of concentrated nutrient solutions as these ions can cause salts to precipitate when preparing concentrated solutions. To fix this issue the best thing would be to use distilled water but – since this is often not an option – the next best thing is to use reverse osmosis water and add a bit of acid (0.5mL/L of nitric acid, other acids may cause other problems) per gallon of concentrated solution. This will ensure that everything gets dissolved and will eliminate the carbonates that can be naturally present within the water. *Of course never, ever use tap or well water to prepare concentrated hydroponic solutions.*

Salts take up volume, take that into account. A very common mistake when preparing solutions is to just add the salts to the final volume of desired stock solution to prepare. This is a mistake since the salts also take up volume. If you want to prepare 1 liter of concentrated solution and you need to add say, 100 g of potassium nitrate, adding 100g of potassium nitrate to 1L of water would generate a solution with a final volume greater than 1L. To avoid this problem always add the salts to half the volume of water and, after the salts have dissolved, complete to the final volume of desired solution.

Add salts from the smallest to the largest quantities. When you prepare hydroponic solutions it is often better – especially when you're starting – to add salts from the smallest to the highest amounts needed. If you make a mistake at some point then you will minimize the amount of mass of salts that has been wasted due to this fact. If you make a

mistake adding a micro nutrient you will only lose a small amount of the other micro nutrients instead of losing a huge amounts of macro nutrients due your order of addition. It is also true that the substances that are added in largest quantities are commonly nitrates and these salts have endothermic dissolutions – meaning they cool solutions upon addition – so it is better to add them last so that they can benefit a bit from the heat generated by the dissolution of the other salts.

The above is not an exhaustive list of pointers but it should save you from some important trouble when preparing your own initial nutrient solutions. Although some of these points may seem obvious to those that have experience preparing their own solutions they may prove invaluable to those who are just starting their journey in concentrated nutrient preparation.