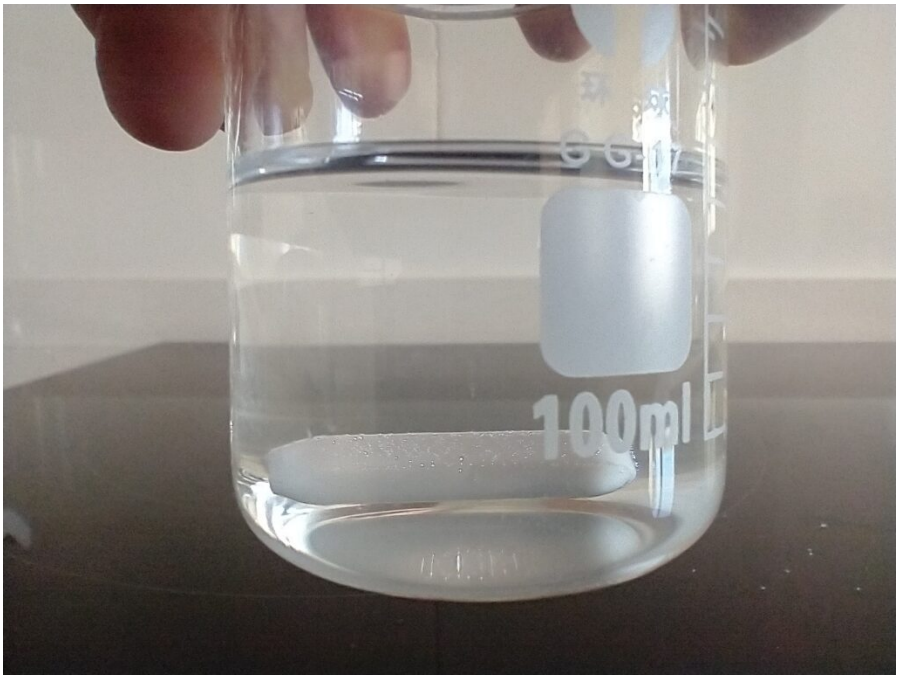
How to make a stabilized ortho-silicic acid solution with only 3 inputs

In a previous post, which you can read here, I gave a procedure for the preparation of a stabilized mono-silicic acid using from potassium silicate. The procedure called for the usage of several stabilizing agents, including carnitine and propylene glycol, with phosphoric acid being used as the acidifying agent.

After trying this synthesis myself and talking with other people who tried this process, it seemed clear that the success rate was low and that the process was just too complicated and imprecise for most people to carry out (especially for the patience needed for the addition of the solid potassium silicate). There is a detailed discussion about this procedure, as well as mono-silicic acid synthesis in this forum thread.



Stabilized mono-silicic acid solution created using the procedure below. Note that mono-silicic acid and ortho-silicic

acid are the exact same thing, they are two names for the same molecule (H_4SiO_4). Another molecule with the same nomenclature is ortho-phosphoric acid (H_3PO_4), which is also called mono-phosphoric acid.

Given these issues, I decided to look for a potentially easier synthesis starting from cheaper, more readily available materials, avoiding the use of Propylene Glycol (which concerned some people) and trying to simplify the steps involved.

The procedure I came up with simplifies the process by relying on the interaction of silicic acid with sorbitol as a stabilizing agent. This stabilization process is well documented in the literature (see here) and is caused by the formation of highly stable polyolate complexes between mono-silicic acid and molecules like sorbitol. These complexes form because molecules like sorbitol have adjacent hydroxy groups in what we call a *threo* configuration. These do not exist in sugars like glucose or sucrose, reason why these do not work for this process.

The raw inputs you will need are as followed

1. A potassium silicate with a high K/Si ratio, such as AgSil 16H. You can also use a liquid potassium silicate, such as Grotek Pro-silicate.
2. Sulfuric Acid (>90%)
3. Sorbitol
4. Distilled water.

If using AgSil16H follow this process first. In a 1000mL beaker, add 70g of AgSil16H and 450mL of distilled water. Stir – ideally with magnetic stirring – until the silicate has all dissolved. This will be the silicate solution.

This is now the procedure to prepare the stabilized ortho-silicic acid solution (700mL):

1. In a 1000mL beaker, add 500mL of distilled water and a

magnetic stirrer.
2. Weigh 200g of Sorbitol and add them to the water.
3. Start the magnetic stirring.
4. After the sorbitol has completely dissolved, during a period of 30 seconds add 100mL of the silicate solution (either as prepared above or a commercial silicate equivalent to the Grotek suggestions above (around 7.5% Si as SiO_2)).
5. Stir the silicate and sorbitol solution for 10 minutes.
6. Add 10mL of >90% sulfuric acid and stir for 5 minutes. The pH should now be lower than 2.
7. The solution can now be stored.

The above process creates a stable mono-silicic acid solution that has an Si concentration of around 1% of Si as SiO_2 and around 0.6% K as K_2O. **Used at 8mL gal it should provide around 20ppm of Si As SiO_2 and 10 ppm of K.**

A previous version of this procedure used 50mL of 80-85% phosphoric acid. However, phosphoric acid seems to generate solutions that are unstable after 1-2 weeks of preparation. Solutions prepared per the above process have been confirmed to be stable for at least 1 month.

Did you try it? How were your results? Let us know in the comments below!

A one-part hydroponic nutrient formulation for very

hard water

What is water hardness?

There are many parameters that determine the quality of a water source. Water that has a composition closer to distilled water is considered of a higher quality, while water with many dissolved solids or high turbidity is considered low quality. Calcium carbonate, magnesium carbonate, calcium sulfate and calcium silicate are some of the most common minerals that get dissolved into water as it runs through river beds and underground aquifers. The carbonates and silicates will make water more basic, will increase the water's buffering capacity and will also increase the amount of magnesium and calcium present in the water.

Water hardness is determined experimentally by measuring the amount of Calcium and Magnesium in solution using a colorimetric titration with EDTA. Although both Calcium hardness (specific amount of Ca) and Magnesium hardness (specific amount of Mg) are measured, total water hardness (the sum of both) is the usually reported value. The result is often expressed as mg/L of $CaCO_3$, telling us how much $CaCO_3$ we would require to get a solution that gave the same result in the EDTA titration.

The Calcium and Magnesium present in water sources with high hardness is fully available to plants – once the pH is reduced to the pH used in hydroponics – and it is therefore critical to take these into account when formulating nutrients using these water sources. *It is a common myth that these Ca and Mg are unavailable, this is not true.*

What about alkalinity?

Water alkalinity tells us the equivalent amount of calcium carbonate we would need to add to distilled water, to get water that has the same pH and buffering capacity. An alkalinity value of 100 mg/L of $CaCO_3$ does not mean that the water has this amount of carbonate, but it means that the water behaves with some of the chemical properties of a solution containing 100mg/L of $CaCO_3$. In this particular case, it means that the water requires the same amount of acid to be titrated as a solution that has 100mg/L of $CaCO_3$.

Water sources with high hardness will also tend to have high alkalinity as the main salts that dissolve in the water are magnesium and calcium carbonates. Since these carbonates need to be neutralized to create a hydroponic solution suitable to plants, the anion contribution of the acid that we will use to perform the neutralization needs to be accounted for by the nutrient formulation.

An example using Valencia, Spain

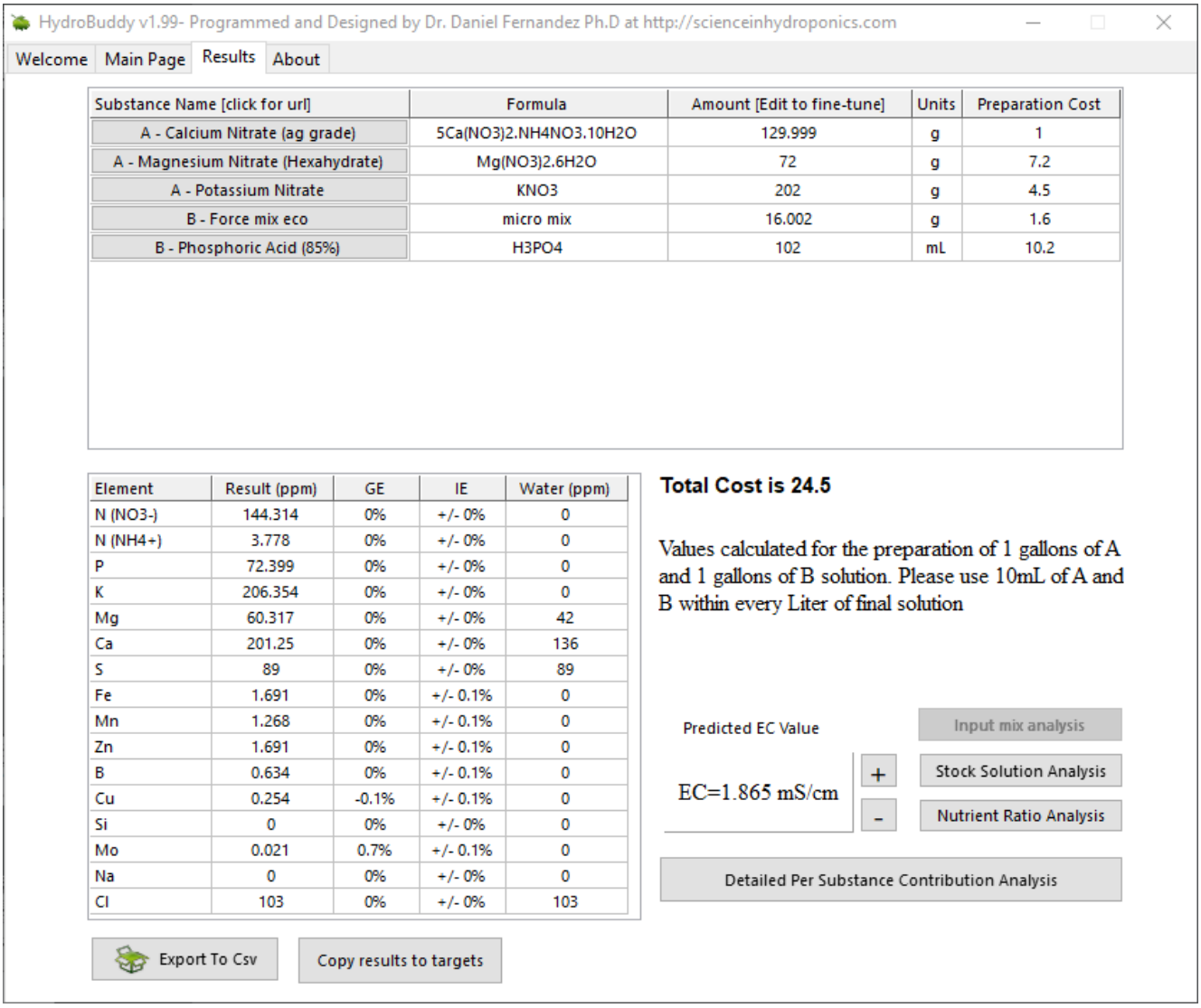
Valencia, in the Mediterranean Spanish coast (my current home), has particularly bad water. Its water has both high alkalinity and high hardness, complicating its use in hydroponics. You can see some of the characteristics of the water below (taken from this analysis):

Name	Value	Unit
Calcium	136	ppm
Magnesium	42	ppm
Chloride	103	ppm
Sulfur	89	ppm
pH	7.6	
Alkalinity	240	mg/L of $CaCO_3$

Typical water quality values for water in Valencia, Spain.
Hard water creates several problems. Since Calcium nitrate is one of the most common sources of Nitrogen used in hydroponics, how can we avoid using Ca nitrate? Since we have more than enough. Also, how can we neutralize the input water so that we can make effective use of all the nutrients in it without overly increasing any nutrient, like P, N or S, by using too much of some mineral acids?

Creating a one-part solution for very hard water

HydroBuddy allows us to input the characteristics of the input water into the program so that we can work around them while designing nutrient solutions. To get around the above mentioned problems – but still ensure I could easily buy all the required chemicals – I decided to use a list of commonly available fertilizers. I used Calcium Nitrate, Magnesium Nitrate, Potassium Nitrate, Phosphoric acid (85%) and a micro nutrient mix called Force Mix Eco (to simplify the mixing process). This micronutrient mix is only available to people in the EU.



HydroBuddy results to create 1 gallon of 1:100 nutrient solution for Valencia's very hard water.

Note that we use absolutely no phosphates or sulfates, since the solution already contains more than enough sulfur (89 ppm) and we need to add all the Phosphorus as phosphoric acid to be able to lower the alkalinity. I determined the amount of P to add by setting P to zero, then using the "Adjust Alkalinity" to remove half of the alkalinity of the water using phosphoric acid. This is more than enough P to be sufficient for higher plants. The above nutrient ratios should be adequate for the growth of a large variety of plants, although they are a compromise and not ideal for any particular type of plant.

Since we are adding no sulfates and the pH of the solution is going to be very low (because of the phosphoric acid), we can add all of these chemicals to the same solution (no need to

make A and B solutions). The values in the image above are for the preparation of 1 gallon of concentrated solution. This solution is then added to the water at 38mL/gal of tap water to create the final hydroponic solution.

Does it work?

I have experimentally prepared the above concentrated solution – which yields a completely transparent solution – and have created hydroponic solutions I am now using to feed my home garden plants. After adding to my tap water – initial pH of 7.6 – I end up with a solution at a pH of 5.6-5.8 with around 1.5-1.8mS/cm of electrical conductivity. The plants I'm currently growing – basil, rosemary, chives, mint, malabar spinach and spear mint – all seem to thrive with the above solution. I am yet to try it on any fruiting crops, that might be something to try next year!

Are you growing using hard water, have you prepared a similar one-part for your hard-water needs? Let us know what you think in the comments below!

New tissue analysis feature in HydroBuddy v1.99

Tissue Analysis

To grow great plants, we need to grow plants that have a healthy mineral composition. Although there are no theoretically established values for what the mineral composition of a plant should look like, we have grown healthy

plants and have established, through analysis of their tissue, what this mineral composition should empirically be. By sampling the leaf tissue from your plants and sending it to a lab for analysis, you can know what the composition of your tissue is and how it compares to healthy plants grown by others.

The question is, can we create a nutrient formulation just from the tissue composition we want to get?

Nutrient solution targets from tissue analysis

Turns out, you can figure out the elemental concentrations that are required in solution to get to certain concentrations in tissue. My colleague and friend – Bruce Bugbee – proposed in this paper about nutrient management in 2004 how this could be done. To achieve this, we make the assumption that all elements taken up by the plant will be deposited as minerals upon transpiration – because minerals cannot leave the plant as gases – so knowing the amount of water that will transpired per amount of tissue grown, we can figure out how much of that element needs to be in the water.

The volume of water required to grow a certain mass of tissue is called Water Use Efficiency (WUE). It is expressed as gram of tissue per liter of water transpired and has values from 3.0 to 6.0. Higher WUE values imply the plant is growing more efficiently, requires less water to grow the same mass of tissue, while a lower WUE implies the plant is less efficient and needs to transpire more to grow. Conditions that increase growing efficiency and decrease transpiration, such as carbon dioxide enrichment and high humidity, tend to increase WUE, while conditions that create inefficient growing – like low humidity with high temperature – tend to decrease it.

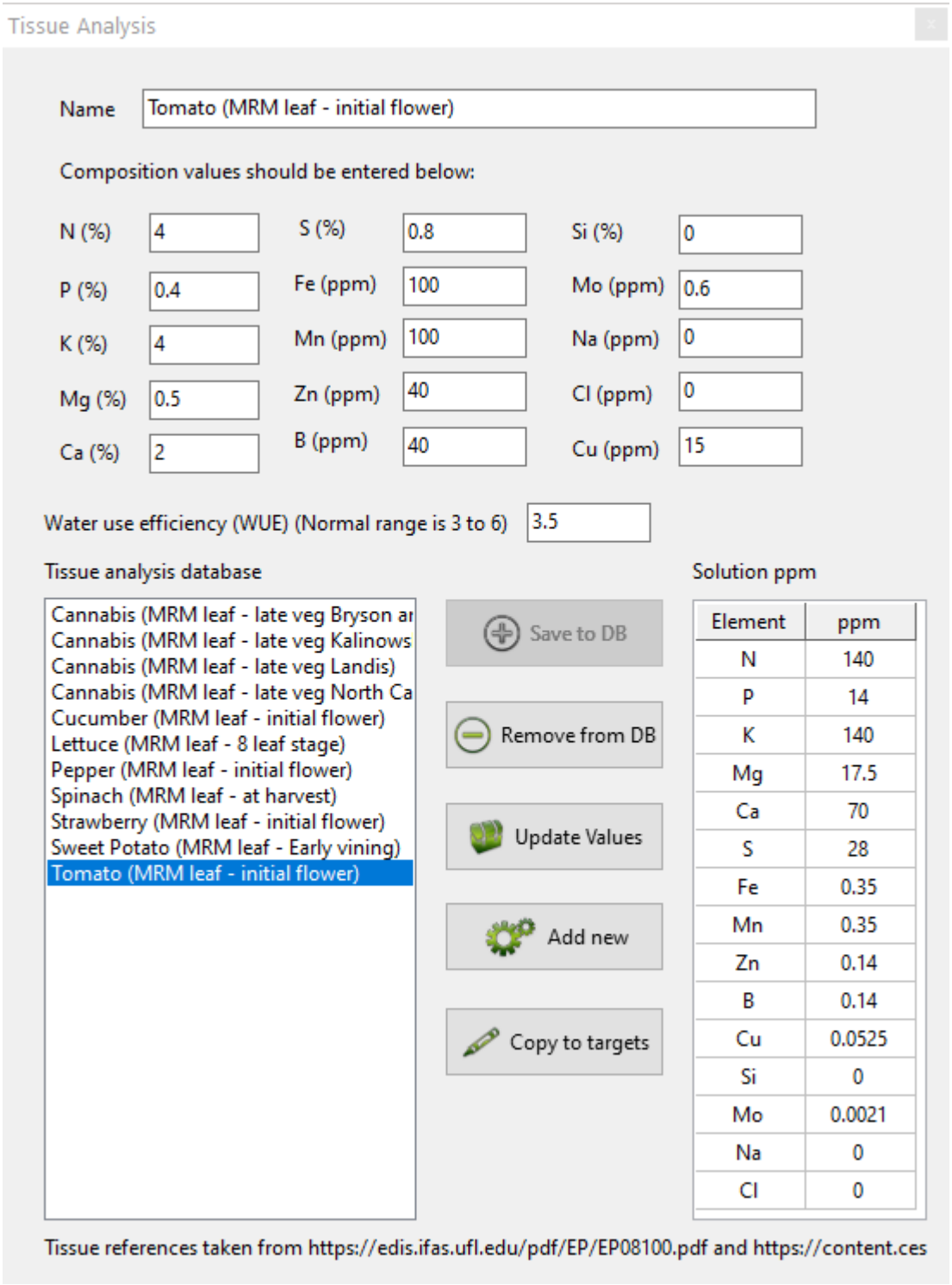
If we grow plants with a solution where we determine the

nutrients according to the WUE and the concentrations in tissue we want, we can create very effective solutions that lower the probability of over accumulation of nutrients in the root zone and the solution. This allows for solutions that require no dumping and create very healthy plants in recirculating systems (for which Deep Water Culture, DWC, is the most common example).

Doing this process in HydroBuddy

From v1.99, HydroBuddy now includes a “Tissue Analysis” dialogue that allows you to use target tissue concentrations and a certain WUE value, to figure out what the required nutrient concentrations in a hydroponic solution would be like. The program also includes a small Database with tissue targets for certain plants and certain stages of development. There are also a couple of links that point you to resources where you can find a wide variety of different plant species and development stages if the ones that interest you are not included in the software’s default DB configuration.

The image below shows you an example where I determined the target solution concentrations required to grow a tomato plant that has the composition expected for a tomato plant in early flower.



Nutrient solution targets for a hydroponic solution to grow tomatoes with a leaf tissue composition equal to that expected for tomatoes under initial flower (MRM = most recent mature leaf). This assumes the WUE is 3.5 g/L.

How do I figure out the WUE?

As you can see, the above process requires you to input the WUE. This ranges from 3 to 6. It is not easy to measure in the

environment, so the best practical solution is to assume your WUE is about 3.5 (the default value), prepare solutions with those concentrations and then observe how the EC of the solution changes as a function of time.

A solution that is prepared with a concentration that would be appropriate for the exact WUE of the plants will have an initial decrease in EC – as nutrients that are taken actively are rapidly taken up – followed by more stable to slightly decreasing EC conditions as uptake changes to be mostly passive. This cycle is repeated when solution is replenished to recover the initial volume in a recirculating system. A solution that is prepared too concentrated will have an increasing EC while a solution that is prepared too diluted will show a consistently decreasing EC. If your EC decreases more sharply with time then you need to assume a higher WUE, if your EC increases then you need to lower your WUE assumption.

Limits of the approach

While this approach can be very useful to create long lasting solutions, especially in recirculating systems, it suffers from some important limitations.

The first is that it doesn’t account for changes in uptake due to changes in pH or availability in solution. This is the reason why the recommendations for elements like Fe and Mn, might be significantly lower than what you commonly see in nutrient solutions. In the above example, the solution requires only around 0.35ppm of Fe, but this means we need 0.35ppm of fully available Fe for the plant, which in reality might mean having 1.5ppm of Fe or more of added Fe, depending on the chemical form of Fe and the pH of the solution.

The above implies that values should not be used without considering the context and that this context might be much more important for some nutrients, for example micro

nutrients, than for other elements, for example K and Ca, for which the availability windows and plant uptake are much more straightforward. The plant characteristics should also be taken into account. While a leaf tissue derived approach might only require 50 ppm of Ca in a lettuce crop, we know we need to feed more due to the poor water transport of this plant into new leaves.

Second, the approach assumes that all we care about is leaf composition. This is a perfectly fine if we are growing leafy greens, but if you're growing a tomato plant, the composition will be heavily split between leaves and fruits as soon as flower pollination ends. For this reason, the nutritional needs of other important tissues – such as sink organs – should be considered very carefully when following this approach. In the case of tomatoes, this might mean feeding substantially higher levels of K, as this element has a much higher concentration in fruits than it has in leaves.

Crops that have changing nutritional needs due to changes in the composition of the tissue formed, require different nutrient solutions as a function of time, as we need to match the overall expected composition of the entire plant, not just the leaves.

Conclusions

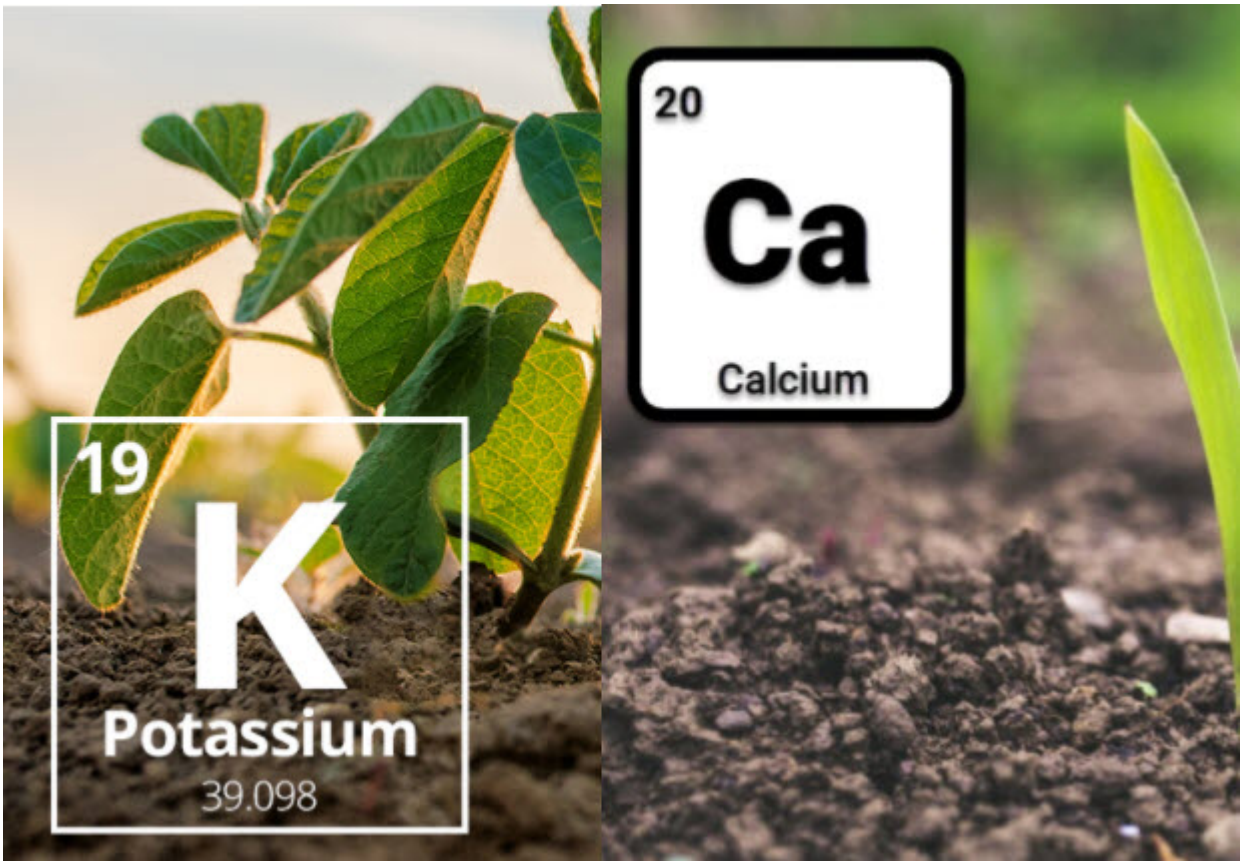
Nutrient formulations do not need to be just trial and error. Up until now, besides a formulation database, HydroBuddy had no feature to help growers create formulations with any scientific basis. This new feature, introduces the ability to use target leaf tissue composition and WUE as a way to guide the initial formulation of nutrient solutions. While you still need experience to figure out when to overrule these values and increase or decrease concentrations, it does provide basic blue prints to build from. An analysis of how a formulation derived from tissue compares with your current formulation

might also give you some insights into whether you are over or under feeding any elements.

Have you use the HydroBuddy’s leaf tissue analysis feature? Leave us some comments below!

The Potassium to Calcium ratio in hydroponics

To have a healthy hydroponic crop, you need to supply plants with all the nutrients they need. One of the most important variables that determine proper nutrient absorption, is the ratio of Potassium to Calcium in the nutrient solution. These two elements compete between themselves and have different absorption profiles depending on the environment, and the plant species you are growing. For this reason, it is important to pay close attention to this ratio, and how it changes with time, in your nutrient solution. In this post, we are going to examine peer-reviewed research about this ratio and how changing it affects the growth, quality, and yield of different plant species.



Two vital elements that compete against each other. Their ratio is fundamental to maximize yields and changes depending on the plant species, environmental conditions and absolute concentrations used

Two ions with very different properties

Potassium and Calcium are very different. Potassium ions have only one positive charge and do not form any insoluble salts with any common anions. On the other hand, calcium ions have two positive charges and form insoluble substances with a large array of anions. This creates several differences in the way plants transport and use these two nutrients.

While potassium is transported easily and in high concentrations through the inside of cells, Calcium needs to be transported in the space between cells and its intracellular concentration needs to be very closely regulated. Calcium can also only be transported up the plant –

from roots to shoots – while potassium can be transported up and down as it pleases.

Calcium transport – happening around cells – is heavily dependent on transpiration, which is what causes water to flow through this space. Potassium transport is not so closely related to transpiration, as it can move directly through the inside of cells in large amounts, which means it can be actively transported through the plant in an effective manner.

Note that the above is a broad over-simplification of Potassium and Calcium transport. If you would like to learn more about this topic, I suggest reading these reviews (1,2).

Competition between K and Ca

Potassium and Calcium are both positively charged, so they do compete to a certain extent. The competition is both because they compete for anions – which they need to be paired with for transport – and for the use of electrochemical potential, which they take advantage of to get transported across membranes. However, they do not have the same transport mechanisms, so the competition is limited.

Table 5. Interaction between EC and K:Ca ratio on nutrient concentration (g kg^{-1}) YFEL of cv. Red Mignonette 3 weeks (maturity) and 3YL 2 and 3 weeks after transplanting

EC	K:Ca	YFEL-wk 3				3YL wk 2	3YL wk 3
(dS m^{-1})		K	Ca	Mg	P	K	K
0·4	1·00:3·50	31·4	11·1	6·1	7·2	46·5	33·6
0·4	1·25:1·00	81·2	10·8	3·4	8·5	64·5	59·9
0·4	3·50:1·00	84·5	10·2	3·7	8·4	66·9	63·6
1·6	1·00:3·50	89·9	13·2	3·6	8·7	65·2	61·6
1·6	1·25:1·00	90·5	10·8	3·5	8·7	64·5	65·2
1·6	3·50:1·00	97·8	9·8	4·0	8·6	65·7	65·1
3·6	1·00:3·50	86·1	7·3	3·9	9·6	59·7	59·2
3·6	1·25:1·00	94·4	10·1	3·0	8·5	60·8	62·6
3·6	3·50:1·00	96·6	4·1	3·3	8·7	67·4	64·4
	l.s.d.[A]	9·9	2·3	0·8	0·9	5·2	4·1

Table taken from this article (3)

The table above illustrates this point. This study (3) looked into different K:Ca ratios in the growing of lettuce and the effect these ratios had on yield, tip burn, and nutrient concentrations in tissue. You can see that at low total concentrations (0.4 mS/cm EC) the K in tissue is very low when the amount of Ca is high relative to K, while at higher EC values (1.6 mS/cm EC), the K concentration remains basically unaffected, even if the Ca concentration is 3.5 times the K concentration. While Ca competes effectively with K when the absolute concentration of both is low, this competition of Ca becomes quite weak as the concentration of K and Ca increase. At very high concentrations (3.6 mS/cm EC), the potassium does start to heavily outcompete the Ca, especially when the K:Ca ratio is high (3.5x).

The above is also not common to all plants. For some plants, the competition of Ca and K actually reverses compared to the results shown above. However, it is typical for low and high absolute concentration behaviors to be different, and for the influence of K or Ca to become much lower in one of the two cases.

Optimal K:Ca ratios

The K:Ca ratio has been studied for many of the most popularly grown plants in hydroponics. The table below shows you some of these results. It is worth noting, that the results that maximized yields, often did so at a significant compromise. For example, the highest yield for lettuce came at the cost of a significantly higher incidence of inner leaf tip burn. In a similar vein, the highest yields in tomatoes, at a 3:1 ratio, came at the cost of additional blossom end rot problems. This is to say that, although these ratios maximized yields, they often did so with consequences that wouldn’t be acceptable in a commercial setup. For lettuce, 1.25:1 proved to be much more commercially viable, while still giving high yields.

Ref	Plant Specie	Optimal K:Ca
4	Rose	1.5:1
5	Tomato	3:1
6	Tomato	1.7:1
7	Marjoram	0.5:1
8	Strawberry	1.4:1
9	Cucumber	1:1
10	Lettuce	3.5:1

Optimal K:Ca – in terms of yields per plant – found for different plant species

You can see in the above results, that fairly high K:Ca ratios are typically required to increase yields. For most of the commercially grown flowering plants studied, it seems that a ratio of 1.5-2.0:1 will maximize yields without generating substantial problems in terms of Ca uptake. As mentioned above, higher K:Ca often push yields further, but with the presence of some Ca transport issues. A notable exception might be cucumber, for which the publication I cited achieved the maximum yield at a ratio of 1:1. However, good results were still achieved for 1.5:1.

Another important point about the ratio is that it is not independent of absolute concentration. As we saw in the previous section, the nature of the competition between K and Ca can change substantially depending on the absolute ion concentrations, so the above ratios must be taken within the context of their absolute concentration. The above ratios are generally given for relatively high EC solutions (1.5-3mS/cm).

Conclusion

The K:Ca ratio is a key property of hydroponic nutrient solutions. While the optimal ratio for a given plant species cannot be known *apriori*, it is reasonable to assume that the optimal ratio will be between 1:1 and 1:2 for most large

fruiting crops and flowering plants that are popularly grown in soilless culture. This is especially the case if the hydroponic solution does not have a low EC. An optimal value below 1:1 is unlikely for most plants, although exceptions do exist in certain plant families that have peculiar Ca metabolisms.

To obtain the largest benefit, it would be advisable to run trials to optimize the K:Ca ratio for your particular crop, by changing the K:Ca ratio between 1:1, 1.5:1, and 2:1. You will likely see important differences when you carry out these trials, which will be useful to determine the highest yielding configuration for your setup. To perform these variations, it is usually easiest to change the ratio of potassium to calcium nitrate used in the nutrient solution.

Have you tried different K:Ca ratios? What do you grow and what has worked for you? Share with us in the comments below!

How to use organic fertilizers in Kratky hydroponics

I've written several posts in this blog about Kratky hydroponics (for example here and here). In this method, you use a bucket, a net pot, a small amount of media, and some nutrient solution, to grow a plant from start to finish. It requires no power or interventions in the case of leafy greens or small flowering plants. However, one of the requirements of a traditional Kratky setup is the use of regular hydroponic nutrients that are created from synthetic inputs. In this post, we are going to talk about the use of organic

fertilizers in Kratky hydroponics, which inputs might work, and which will be problematic.

Plant grown in a traditional Kratky setup using synthetic fertilizers

The types of organic inputs

When people talk about “organic fertilizers”, they usually refer to inputs that can be used in the growing of organically certifiable foods. The easiest way to fit this definition is to look at the inputs that are listed by organizations like OMRI. However, among OMRI-listed products, we have significant differences in where the products come from, and this makes a huge difference in whether or not we could use them in a Kratky setup.

For the purposes of this post, we can divide the OMRI-listed products into three categories. We have mined materials, which are extracted and used in their raw form from the earth. We also have animal or vegetable sourced products, which are byproducts of some animal or vegetable industry, and we have processed products, which involve some postprocessing or mixing of products in the former categories.

In the first category of products, we have things like mined magnesium sulfate, potassium sulfate, rock phosphate, sodium

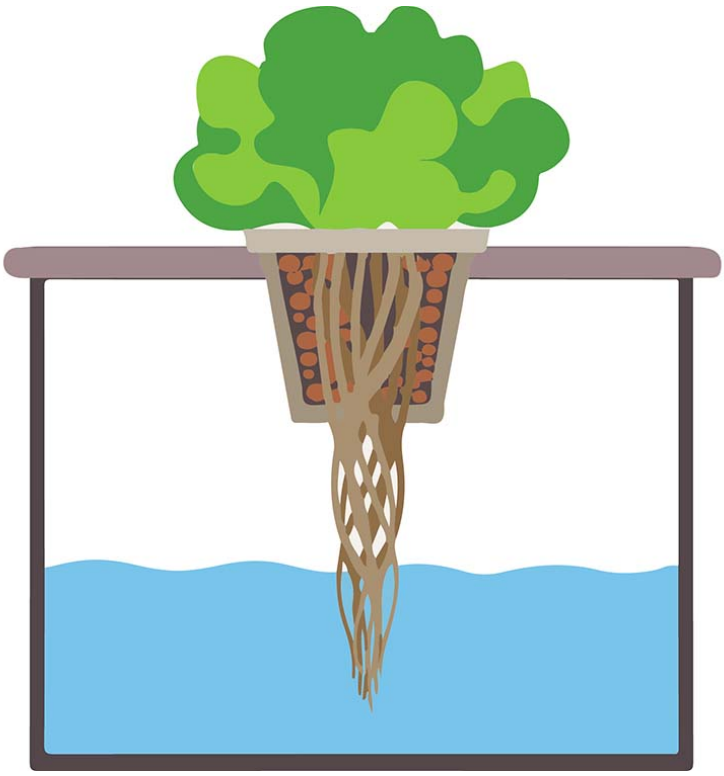
nitrate, or limestone. In the second category, we have things like fish emulsion, kelp extract, blood meal, and bone meal, while in the third category we have products like the Biomin series of transition metal chelates or any liquid or solid organic fertilizer blended products.

Why origin matters

The type of organic input matters, because Kratky hydroponic systems lack one important element. Oxygenation.

Since oxygen is not going to be injected into the nutrient solution, any input we use that requires oxygen for decomposition or absorption, or that requires oxygen for its proper uptake, is not going to work well. If you add any animal or vegetable product to a Kratky setup, the lack of oxygen in the solution is going to give way to the growth of anaerobic organisms that are going to be detrimental to plant growth and will lead to root rot.

Things like blood meal – which would be great amendments in soil with good aeration where oxygen can do its job – turn into foul mixes when put into a Kratky setup. This is because a Kratky setup has a stagnant body of water that is going to turn into a very unfavorable medium for plants as soon as we add anything that creates a heavily reducing environment.



A traditional Kratky setup. Note that the solution at the bottom is stagnant and not actively oxygenated in anyway. Only the oxygen that diffuses from the air gets into the water. This is enough to keep the submerged roots alive, provided that the solution itself does not act as a sink for oxygen. In these cases, root rot is quickly experienced.

Plant roots can tolerate a relatively oxygen-deprived solution to some extent, provided that enough root mass is above the water to take in oxygen, but they cannot tolerate a solution that is rid of all oxygen by anaerobic microbial activity. This is because oxygen deprivation makes the plant more vulnerable to attack by pathogens and hinders the respiration of plant roots, which is needed for root survival.

Which inputs can you use

In general, any input that heavily removes oxygen cannot be used as-is. This means that anything that contains plant or animal proteins, fats or carbohydrates, is not going to work well. Inputs that are heavily rich in bacteria or fungi, even beneficial ones, are also going to fail. This is because these beneficial microorganisms also require oxygen and, when they

are put in a Kratky solution and die, they are digested by anaerobic organisms that can take their place.

Animal or vegetable inputs that are relatively inert in origin, such as bone meal, would not be problematic, but their ability to release nutrients is going to be limited in a Kratky solution. Mined inputs are going to be mostly fine. Soluble ones, like mined magnesium sulfate and potassium sulfate, are ideal replacements, as they are chemically identical to the synthetic ones, except for a higher content of impurities due to their raw origin. However, it will be difficult to provide enough nitrogen in an organic Kratky hydroponic setup using only this type of inputs.

A potential solution

Since the problem is mainly oxygen deprivation, we can use an organic hydroponic solution, as long as it is processed for long enough to completely eliminate the oxygen depriving capacity of the inputs. As an example, you can follow my instructions on preparing an organic hydroponic solution. This requires fermenting of the solution for a significant period of time, in order to ensure most of the oxygen requiring reactions have been carried out.

To use this solution in a Kratky setup, we would need to give it a longer period of time. We can verify that the solution is ready for Kratky by using an ORP meter and checking that the solution is at an ORP above 300mV after removing active oxygenation for a day. This means that the solution is able to keep enough dissolved oxygen and that most of the oxygen-hungry processes in the solution are done. This might take substantially longer than the 12-15 days suggested in my original article, probably around 30 days.

Another important step is the removal of bacteria and fungi, which could be very problematic once the solution reaches the stagnant conditions of the Kratky setup. To do this, the

easiest solution would be to run the solution through a UV filtering system, in order to make sure all fungi and bacteria are removed from the solution. This might sound counterintuitive, but the Kratky system conditions are not ideal growing conditions for plants and do require us to minimize oxygen sinks in the system.

Conclusion

You can run a Kratky system using an organically derived fertilizer. However, it is not straightforward, as we need to consider that a Kratky system lacks the oxygenation required to carry out a lot of the processes that are taken for granted in organic growing (such as protein decomposition). Without aeration of the solution, we need to provide an organic solution that has already exhausted its hunger for oxygen and can already provide nutrients in a manner that is available to plants. We also need to ensure we add no fungi or bacteria that can work anaerobically and attack roots in the stagnant Kratky solution conditions. We can use tools like long-term fermentation with aeration, ORP meters, and UV systems to achieve this goal.

Have you ever grown in a Kratky setup using organic fertilizers? Let us know about your experience in the comments below!

The importance of accuracy in hydroponic nutrient

preparation

When you prepare your own concentrated hydroponic nutrients, you need to carry out a significant number of measurements. As a consequence, you will deviate from your intended preparation by the errors inherent to these operations. Plants tolerate a significant array of conditions, so these errors – even though sometimes quite big – are often not big enough to kill plants and are therefore ignored by growers. These errors will, however, greatly hinder your ability to optimize and evolve your crop nutrition to a higher standard. In this post, we will talk about these errors, why and how they happen, when they are important, and how you can minimize them in order to obtain more reproducible results.


The markings in buckets can carry high systematic and random errors.

Types of error

Systematic Error

There are two types of errors that happen when anything is measured. The first is systematic error, which is the error inherent to calibration problems of the instrument. For example, you might be using a 1 gallon jug to prepare concentrated nutrients and always filling the jug to a mark you made on it. This mark is not going to be 1 gallon, but probably significantly over or under it. As long as you always use the same jug and fill to the same mark, this large deviation from 1 gallon will always be the same. As long as the measuring instrument is unchanged – meaning not recalibrated – the systematic error always remains the same in sign and magnitude.

Random Error

The second type of error relates to the randomness of the measuring process. Imagine that you used a sharpie to make the mark on the above-mentioned one-gallon jug, and you always try to measure to the same mark. The mark has some width, sometimes you will fill your jug up to the bottom of the mark, sometimes up to the top. Sometimes the surface where you place the jug where you measure will not be perfectly leveled, so the mark will be off because it will be higher at one side of the jug vs the other, etc. This error changes randomly, every time you measure. One time you might be +1%, the other -4%, etc.

Where the biggest errors happen

When you make your own hydroponic nutrients, you will be measuring two things: volume and mass. These two measurements will both carry systematic and random errors. The errors in scales are more obvious, so growers will always make an effort to get scales that are accurate enough for the measurements they want to make. For small growers, this means getting scales that can measure +/-0.01g with a decent capacity, normally 500g is fine. Buying weights to properly calibrate these scales is also recommended, in order to reduce systematic errors as much as possible.

However, always make sure you read at least 3 significant digits when making a weight measurement. This means if you need to measure 1.673485g, you need a scale that measures at least 2 digits, so that you can measure 1.67 +/- 0.01g. This will keep your error below the 1% mark. This is why it is often common to also get a +/-0.001g scale, to measure things like sodium molybdate. You can also go around this problem by preparing more concentrated solution, as your weights become larger, with larger volumes.

Volumes however are where the largest errors are accrued. Most growers will use non-calibrated receptacles to measure volume. The fact that something has a line drawn on it with a volume marking, does not mean that this line is accurate. The systematic errors in these receptacles are usually very large because these were never intended for accurate measurements of volume. **Things like buckets, beakers, tanks, and jugs, should not be used to measure volumes**. Wide containers, like buckets and tanks, also enhance errors that relate to parallax – your ability to judge whether a level of water is at a line – so the random component of your error will be quite large.

Consequences in nutrient values

In the best cases – for jugs, buckets, and tanks – the systematic error is around 10% with a random error of +/- 5% (3 sigma). If you are preparing a concentrated solution where the final expected concentration after dilution is 200 ppm of K, then this means that your actual K value in solution will start by being 10% over or under it – depending on which way the systematic error of your volume measurement goes – and then deviate +/-5% from there. This means that you are expected to get values all the way from 170 to 230 ppm in the final solution.

This is fine as far as keeping plants alive goes. A solution with 170 ppm will keep plants alive as well as a 230ppm solution would. This is the reason why most growers don't see an immediate need to reduce these errors. If you're growing healthy plants and you have less or more than what you intended, what is the problem?

How inaccuracy affects your process

There are three ways in which having inaccurately prepared solutions can affect your process. The first is that it makes you very vulnerable to changes. The second is that it makes it

difficult for you to effectively optimize your setup, and the third is that it prevents others from being able to reproduce your results.

Changes in your setup can affect you deeply

Let’s say you optimized your nutrients with time and found that the optimal is 200ppm of K. In reality you have a bucket that always measures 10% less volume and you randomly deviate +/- 5% from that as well. This means that your final solutions are majorly in the 210-230 ppm range. Your trusty plastic bucket then cracks and you need to go and buy another one, you suddenly find that you’re not getting the same results. Now you have a bucket that just by chance, happens to measure the volume more accurately. You are now feeding 190-210ppm, substantially less K. You never knew that, you’re confused, you’re preparing everything the same way.

Your ability to optimize is hindered

The second problem is similar. Let’s say you prepared a batch of concentrated solution to compare feeding K at 180 ppm and K at 200 ppm. You prepare a single-stock solution to carry out the test. This bucket has a systematic error of +10% and a random error of +/-5%. For this batch, the solution happens to be 6% more concentrated than intended (+10% systematic, -4% random), so you end up with 190.8ppm and 212ppm. You find out that the 200 ppm preparation works better, so you decide to use it.

However, you run out of the stock solution you prepared for the experiment, so you prepare it again. However, you incur a different random error in this preparation – remember random errors are different every time you measure – and you end up being with a +1% random error, so a +11% total error. Your results are not as good as before, you don’t know why. The

reason, you're feeding 222ppm while in your previous experiment you had fed 212ppm. All while thinking you were feeding 200 ppm.

It becomes hard to share

Systematic and random errors can make effective sharing of results impractical. Imagine you have optimized your setup to the point where you're sure that the solution you prepare is the best one for a given plant under some given conditions. Then, you want to share this with another grower and tell him how to mix your formulation. This person tries it and tells you that your solution doesn't actually work the way you think. You might both be aiming for the same targets but hitting completely different numbers in reality. When sharing, it is important to share the numbers you aim for, as well as the error related to these values.

How to reduce errors

Prepare highly accurate small scale solutions

The easiest way to reduce errors when preparing hydroponic solutions is to base all preparations on small-scale experiments where the preparation can be done much more accurately, using calibrated volumetric material. Watch my videos on preparing hydroponic solutions, how to correctly prepare dilutions and how to characterize stock solutions, to learn more about how this is done.

Volumetric flasks can be used for highly accurate small scale preparations

The idea is that these small-scale preparations can tell you things such as: the amount of water you need to add for a given volume of stock solution, the expected conductivity of dilutions, and the expected density of the stock solution. Remember that salts take up volume, so to prepare 1 gallon of a concentrated stock solution you will need much less than 1 gallon of water. With this information, you can then prepare larger amounts of stock solutions, since you know the exact amount of water to add for a final volume, which you can accurately measure with a flow meter instead of having to use markings of any kind. You can then use the density measurement to check the accuracy of the preparation.

Perform fewer measurements

Every measurement you make incurs an additional error. It is

better to prepare 2 concentrated nutrient solutions than to have 10 solutions with the salts being separated because you need to make 8 fewer volume measurements. If you minimize the number of measurements that you need to do to arrive at the nutrient solution that is fed to plants, you will also minimize the error incurred in these measurements. Minimize measurements from instruments with high errors. If your volumes have much more inaccuracy than your weights, prioritize lowering the number of times you measure volume vs weights.

Conclusion

Accuracy is something to strive for. It closes no doors, only opens them. It is not about being overly fuzzy or obsessive about it, it's about using it to help you get better. Better practices, lower errors, more reproducibility, more learning. It's a virtuous cycle. Errors are always there, whether you're aware of them or not. Ignore them at your own peril.

If you have a process that is inaccurate that generates significant variations in your nutrient solution makeup, then these will be a problem, one way or another. You might be unable to judge whether changes in your crop are due to errors or due to changes, you might be unable to reproduce results and you might find yourself unable to meaningfully share results and explore with others. High accuracy is often not substantially expensive in hydroponics – instruments for accurate small-scale preparation are generally below the 200 USD mark total – and they can dramatically enhance the quality of your solutions and the conclusions you can make from experiments.

Do you prepare your own nutrient solutions? Do you know what your systematic and random errors are? Share with us in the comments below!

My Kratky tomato project, tracking a Kratky setup from start to finish

Fully passive, hydroponic setups are now everywhere. However, it seems no one has taken the time to diligently record how the nutrient solution changes through time in these setups and what problems these changes can generate for plant growth. In my Kratky tomato project, I will be closely monitoring a completely passive Kratky setup from start to finish. In this post, I will describe how this project will work, what I will be recording, and what I'm hoping to achieve. Check out the youtube video below for an initial intro to this project.

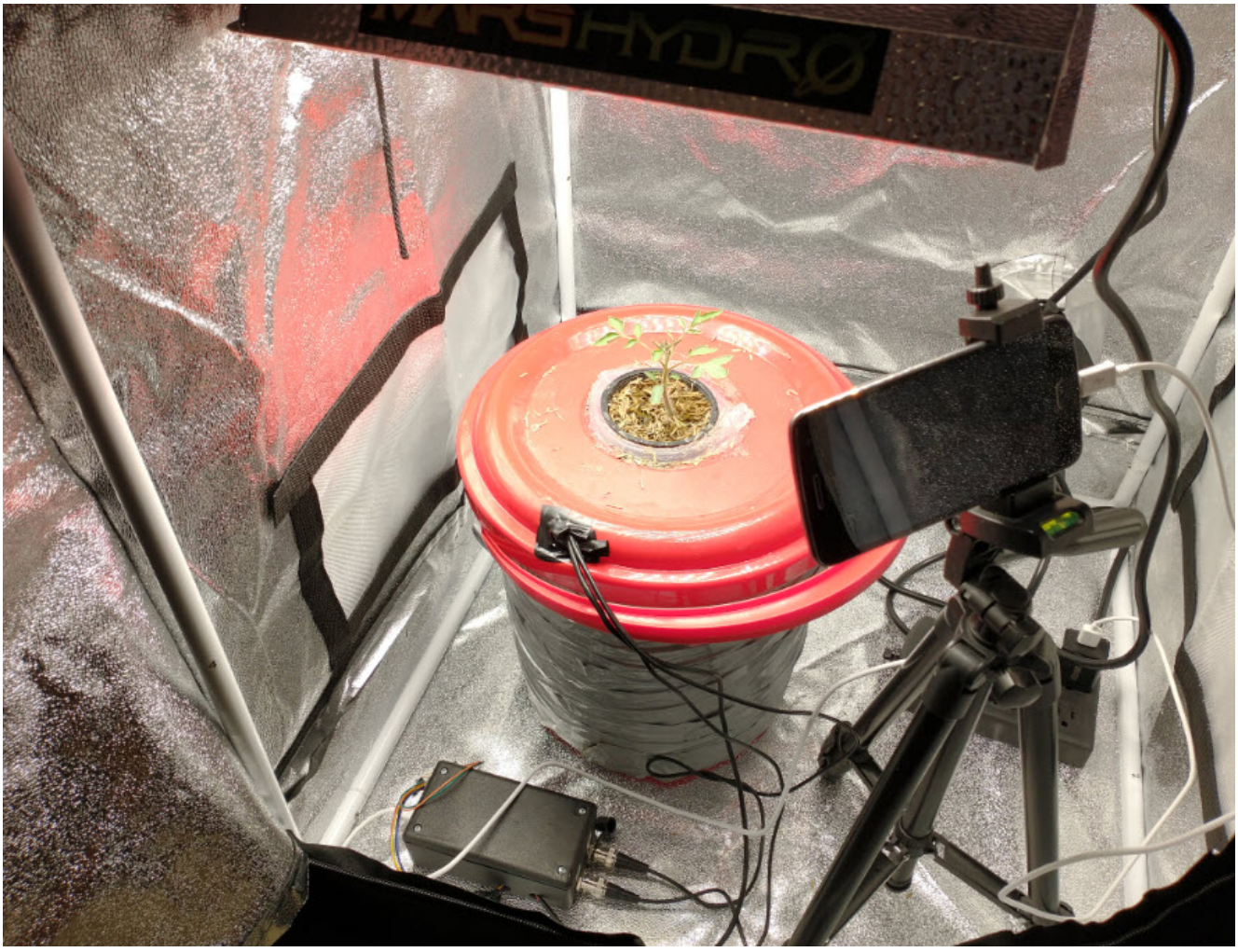
Introduction video for this Kratky project.

The goals

It is tough to grow large flowering plants using truly passive Kratky setups (read my blog post on the matter). We know this is because of issues related to their increased water uptake and the large nutrient and pH imbalances these plants create in nutrient solutions. However, I haven't found any data set that shows how these problems develop as a function of time. By measuring different variables in a Kratky setup through an entire crop cycle, I hope to gather data to help us understand what goes wrong, why it goes wrong and when it goes wrong. With this information, we should be able to develop better nutrient solutions and management techniques, for more successful Kratky hydroponic setups for large flowering plants.

The setup

The setup is a 13L bucket wrapped in duct tape – to prevent light from entering the system – with a hole at the top and a net pot containing a tomato plant. The tomato – which I have named Bernard – is an indeterminate cherry tomato that was germinated in the net pot. The net pot contains a medium consisting of 50% rice hulls and 50% river sand. The bucket has been filled with a store-bought generic hydroponic nutrient solution up to the point where it touches the bottom of the net pot. Furthermore, the bucket is placed inside a grow tent and receives 12 hours of light from a Mars Hydro TS 600 Full Spectrum lamp. The light has been initially placed around 10 inches above the plant and will be moved as needed to maintain proper leaf temperature and light coverage of the plant.



The experimental Kratky setup. You can see the project box

housing the Arduino and sensor boards at the bottom. Bernard has been growing for 2 weeks and is already showing its second set of true leaves.

The measurements

I will be monitoring as many variables as I can within this experiment. To do this I have set up an Arduino MKR Wifi 1010 that uses self-isolated uFire pH and EC probes, a BME280 sensor to monitor air temperature and humidity, and a DS18B20 sensor to monitor the temperature of the solution. I will also be using Horiba probes to track the Nitrate, Potassium, and Calcium concentrations once per day. All the Arduino's readings are being sent via Wifi to a MyCodo server in a Raspberry Pi, using the MQTT messaging protocol. The data is then recorded into the MyCodo's database and also displayed in a custom dashboard. The ISE measurements are manually recorded on a spreadsheet.

The dashboard of my MyCodo server, showing the measurements of the system as a function of time. All readings are also recorded in the MyCodo database for future reference and processing.

Furthermore, I am also taking photographs every 15 minutes – when the lights are on – using a smartphone. This will allow

me to create a time-lapse showing the growth of the plant from the very early seedling to late fruiting stages.

Conclusion

I have started a new project where I will fully record the complete development process of a large flowering plant in a Kratky setup. We will have information about the EC and pH changes of the solution, as well as information about how different nutrient concentrations (N, K and Ca) change through the life of the plant. With this information, we should be able to figure out how to modify the nutrient solution to grow large flowering plants more successfully, and what interventions might be critical in case fully passive growth is not possible.

I will continue to share updates of this project in both my blog and YouTube channel.

What do you think about this project? Do you think Bernard will make it? Let us know in the comments below!

Kinetin, a powerful hormone for flowering plants

Kinetin was the first cytokinin ever discovered. Scientists have used it extensively to stimulate cell division in tissue culture, as it is a powerful growth hormone. However, there isn't a clear understanding of the effects of kinetin in large flowering plants, reason why it hasn't been widely used as an additive in plant culture. In this post, we are going to take a look into the practical application of kinetin. We are going

to look into published research and discuss whether kinetin could be used to enhance plant yields. I will refrain from discussing the history and chemical structure of kinetin, for a basic introduction about kinetin and its history, I suggest reading this paper (1). I will also use some information contained in this review (5).

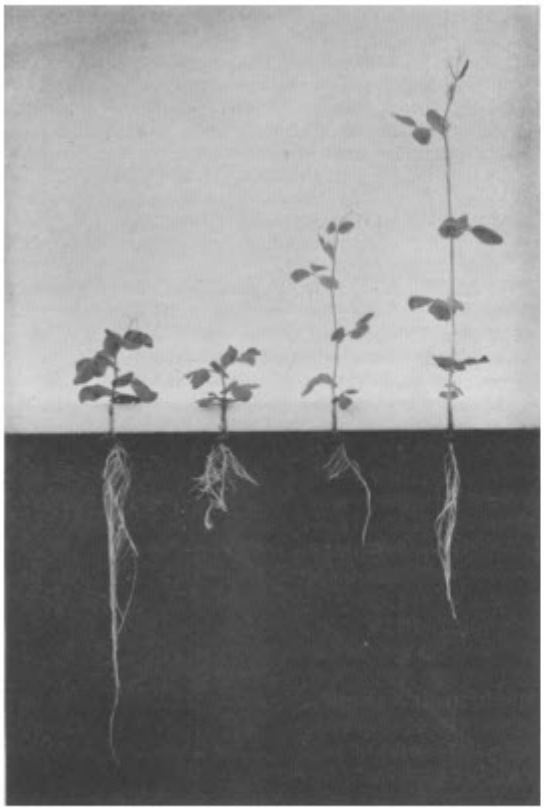


Fig. 5. Comparative inhibitory effects of kinetin and N^6-benzyladenine on the height of the 'Alaska' pea.

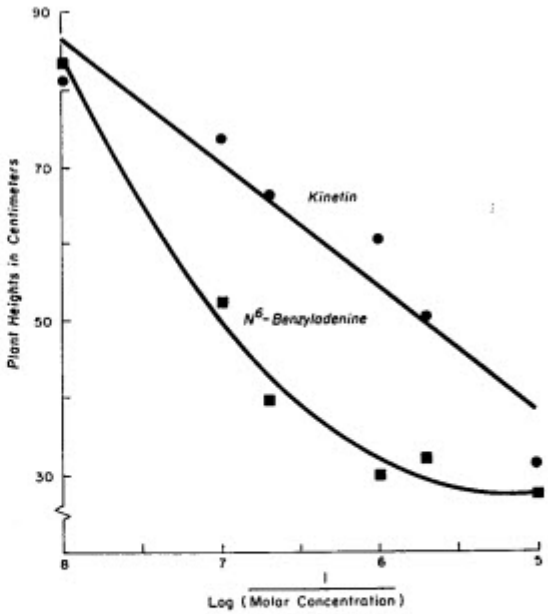


Fig. 4. Effects of kinetin and gibberellin, singly and in combination, in the solution culture root medium on internode elongation of the 'Little Marvel' dwarf pea. Left to right: control (no kinetin), kinetin 10^{-6} M, kinetin 10^{-6} M + gibberellin A_3 10^{-6} M, and gibberellin 10^{-6} M. Plants photographed after 10 days' exposure to the chemical stimuli.

Tomatoes, peas and cucumbers grown in solutions containing kinetin were significantly shorter. Root and flowering changes were also present. Taken from (2).

The effects of exogenous kinetin

In tissue culture, what kinetin does seems to be clear, it promotes cell division in the presence of auxins. However, for large plants in soilless media, the effect does not seem to be that straightforward. One of the first thorough studies of kinetin in flowering plants was done in the early 1960s (2). In this study, tomatoes, cucumbers, and peats were grown in solutions containing different concentrations of kinetin,

going from 10^{-5} to 10^{-7} molar. The researchers showed that kinetin in solution behaved like a gibberellin inhibitor, directly suppressing plant height as a function of concentration. The plants developed several root abnormalities and changes in their flowering cycle, with kinetin inhibiting flowering in tomatoes, but accelerating it in peas.

You can see in this study that the effective concentration is quite low. The range of kinetin concentrations tested goes from 0.0215mg/L to 2.15 mg/L. These values are quite small compared to the amounts of other hormones, such as IBA or NAA, generally used in plant culture. The concentration of kinetin plays a key role in its effect. A 2008 study on red goosefoot (3) shows the strong impact kinetin concentration can have. These researchers showed that low concentrations of kinetin increased bud formation and increased the height of the apical meristem, while large concentrations inhibited flowering and made the plants shorter.

The entire literature on exogenous kinetin applications is therefore split between apparently contradictory effects. Some studies show effects that are more in line with a gibberellin inhibitor, with shorter plants, while others show stimulation of shoot growth. What you get is dependent on concentration and plant species, making kinetin a hard hormone to use. Use too much and you might compromise flowering and yields, use too little and you might have undesirable elongation effects or simply no effects at all (4, 6).

Kinetin can also have an effect on the sex determination of plants. For example, kinetin induces female flowers in cannabis and can ameliorate the production of male flowers in female plants (12).

Kinetin foliar sprays

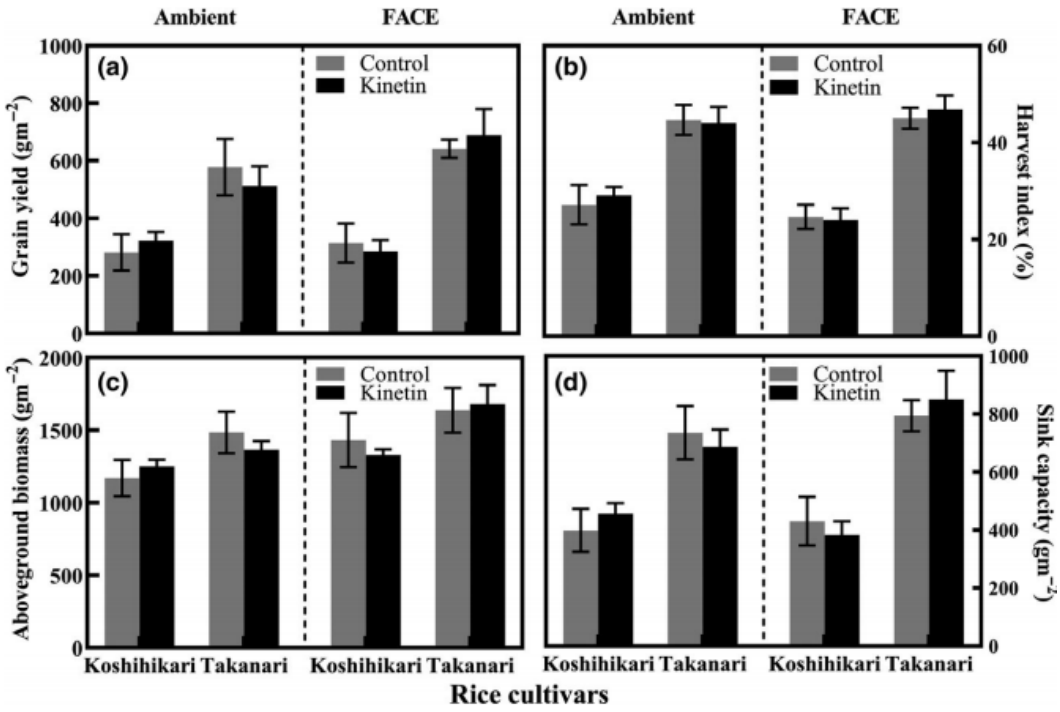
The mode of application makes a big difference as well. While

most of the root studies I read using kinetin kept their application rates below 3mg/L, many foliar studies explore kinetin application rates that are significantly higher. In this study (9), for example, they perform kinetin applications at 100 ppm. From the foliar studies I read, I found this study (7) particularly interesting. In it, kinetin applications at 2.5, 5, and 10 mg/L were done using foliar spraying on tomato, cucumber, and pepper plants.

The researchers found that the cucumbers had an excellent response to the 2.5 mg/L treatment, with taller plants, larger leaf area, and bigger yields, while they showed negative responses to the 10ppm treatment, with lower yields. While tomatoes showed a similar response, peppers gave their best results with the 10 ppm kinetin sprays. This again highlights not only that plants will respond negatively to excessive doses of kinetin, but that this response is significantly species-dependent.

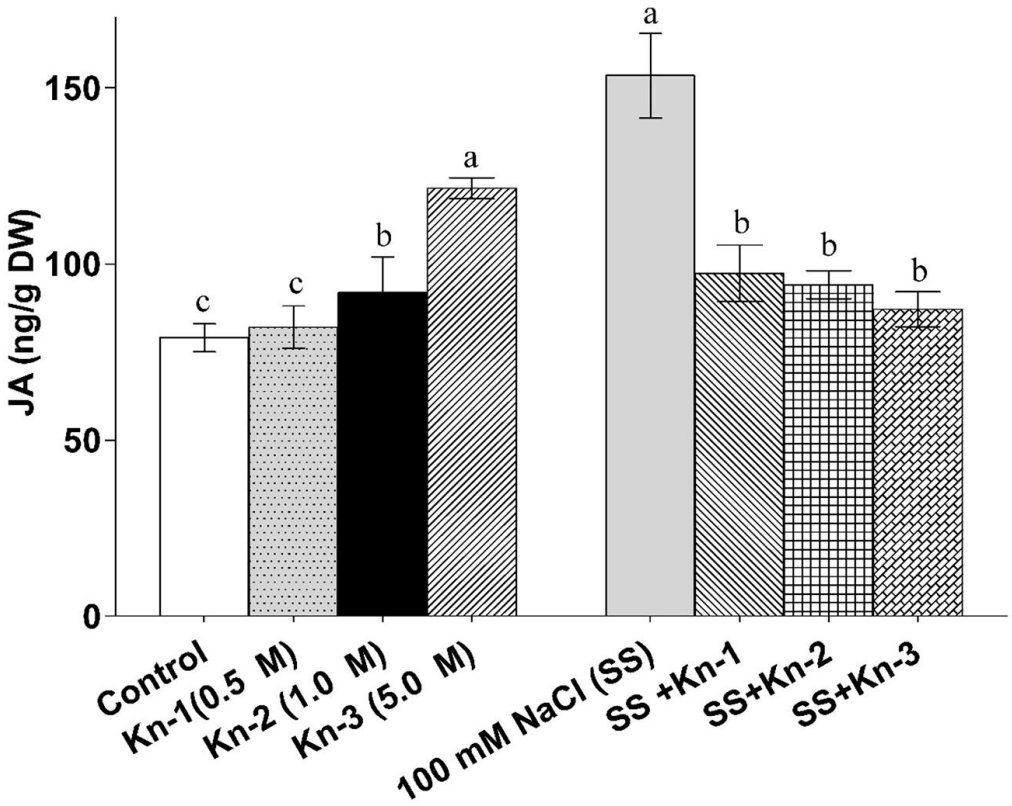
Environmental conditions

Furthermore, environmental conditions can play a significant role in the effects of kinetin. This study (8) found that kinetin could help rice plants give better yields under carbon dioxide enrichment. However, this worked only for some of the varieties of rice used. For the varieties for which it worked, kinetin applied as a foliar at 10.75 ppm was able to enhance the carbon dioxide fertilization effect.



Effect of kinetin application in several different rice cultivars with or without carbon dioxide enrichment (8)

Other environmental conditions, such as salinity stress and oxidative stress, can also play a big role in the effect of kinetin. As a strong antioxidant, kinetin can help plants deal with oxidative stress (10). It has also been tested many times as a way to deal with salinity-induced stress, for example, see this article on kinetin applications in soybeans (11). In this last study, you can see how kinetin upregulates the gibberellin biosynthesis pathway when it was actively suppressed by the high salinity. Some effects, such as the production of jasmonic acid, are actually opposite in the control and in the salinity-induced environments as a function of kinetin concentration.



Changes in jasmonic acid content for soybean plants grown with or without salt stress and treated with kinetin. Kinetin increases JA when no salt stress is present and decreases it otherwise.

Conclusion

Kinetin can be a powerful and versatile hormone in flowering plants. It can be used to achieve a variety of different effects, including making plants shorter, increasing budding sites, increasing yields, or relieving sources of stress. However, the choice of concentration, method, and application time is critical and can lead to completely opposite effects if not done correctly. Low applications tend to increase growth and leaf area, while larger concentrations will show an effect similar to a gibberellin inhibitor. However, the concentrations that work best for a given plant cannot be known before experimentation is done. However, do consider that higher concentrations consistently lead to decreases in yields.

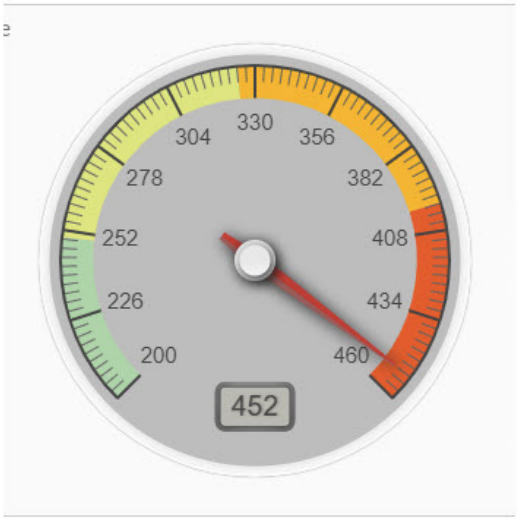
If you want to use kinetin in your crop, start with a foliar

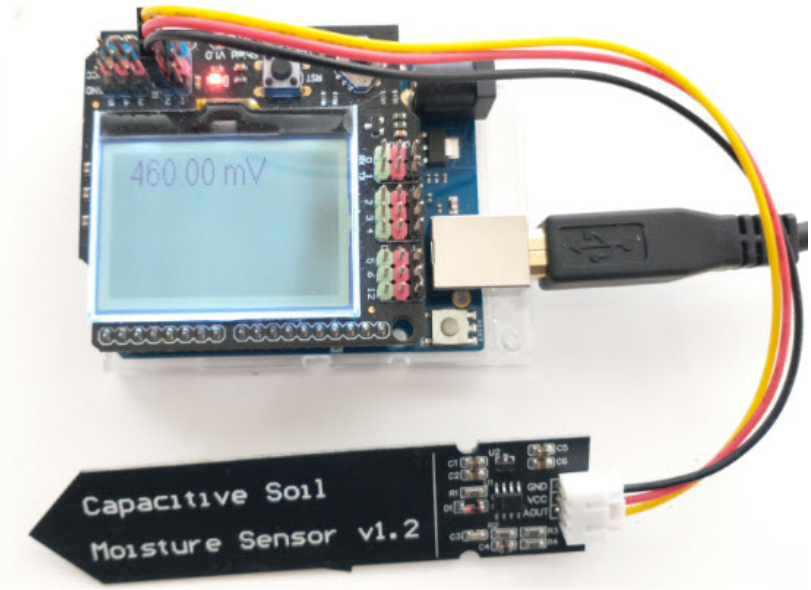
dose at around 2ppm and take note of the effects. From there, you will be able to gauge whether you want to have a higher or lower concentration of kinetin. If the dose is too high, you will start to see some negative effects. Also, time your applications so that they are in line with the effects you want to achieve. If you want to feed kinetin through the roots, use an even lower concentration and make sure your applications are properly timed, avoid having permanent exposure of roots to kinetin, as this is likely to be negative.

Have you ever used kinetin in your crops? What concentrations have you used and what effects have you seen? Let us know in the comments below!

Arduino hydroponics, how to build a sensor station with an online dashboard

In a previous post about Arduino hydroponics, I talked about some of the simplest projects you could build with Arduinos. We also talked about how you could steadily advance towards more complex projects, if you started with the right boards and shields. In this post, I am going to show you how to build a simple sensor station that measures media moisture and is also connected to a free dashboard platform (flespi). The Arduino will take and display readings from the sensor and transmit them over the internet, where we will be able to monitor them using a custom-made dashboard. **This project requires no proto-boards or soldering skills.**





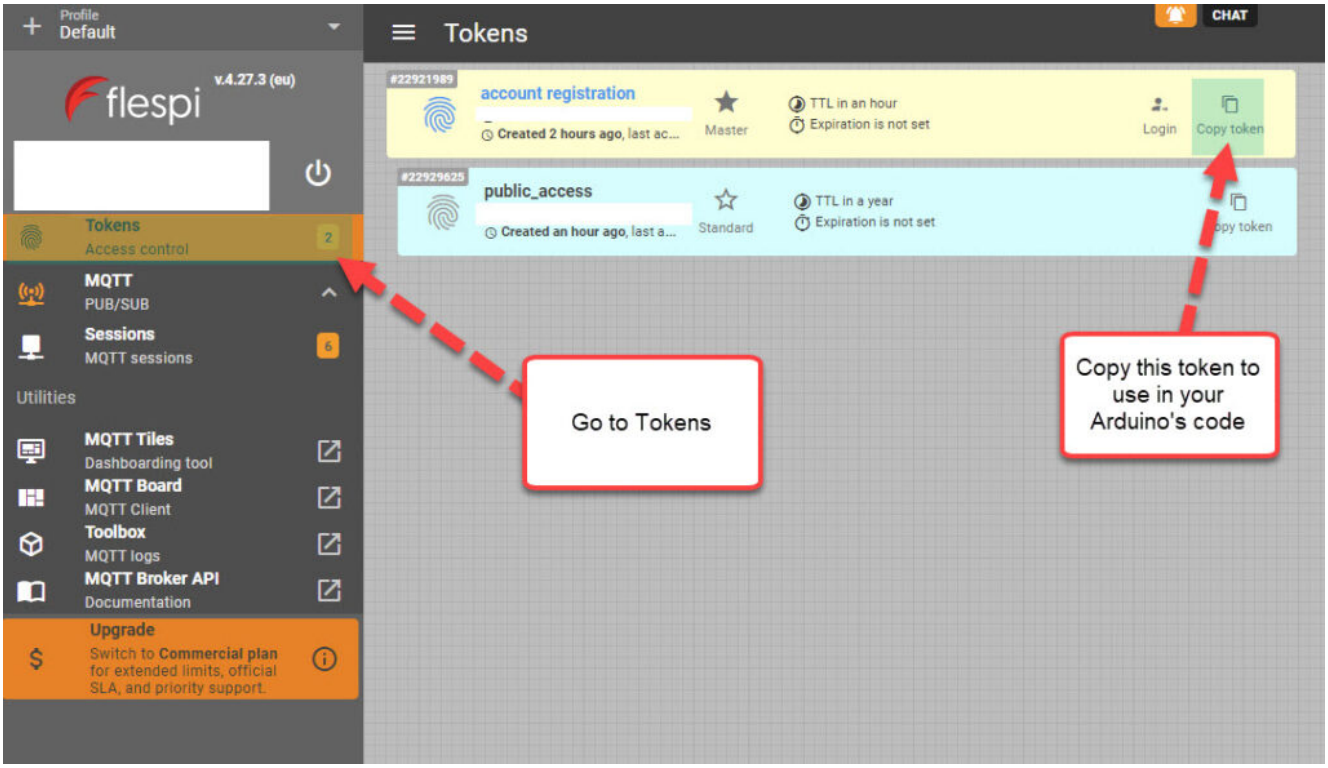
An Arduino Wifi Rev2 connected to a moisture sensor, transmitting readings to an MQTT server hosted by flespi that generates an online dashboard

The idea of this project is to provide you with a simple start to the world of Arduino hydroponics and IoT interfacing. Although the project is quite simple, you can use it as a base to build on. You can add more sensors, improve the display, create more complicated dashboards, etc.

What you will need

For this build, we are going to use an Arduino Wifi Rev2 and an LCD shield from DFRobot. For our sensor, we are going to be using these low-cost capacitive moisture sensors. This sample project uses only one sensor, but you can connect up to five sensors to the LCD shield. Since this project is going to be connected to the internet, it requires access to an internet-connected WiFi network.

Additionally, you will also need a free flespi account. Go to the flespi page and create an account before you continue with the project. You should select the MQTT option when creating your account since the project uses the MQTT protocol for transmission. After logging into your account, copy the token shown on the “Tokens” page, as you will need it to set up the code.



Copy the token from the “Tokens” menu in flespi

Libraries and code

This project uses the U8g2, ArduinoMQTTClient and WiFiNINA libraries. You should install them before attempting to run the code. The code below is all you need for the project. Make sure you edit the code to input your WiFi SSID, password, and Flespi token, before uploading it to your Arduino. This also assumes you will connect the moisture sensor to the analogue 2 port of your Arduino. You should change the ANALOG_PORT variable to point to the correct port if needed.

```
#include <Arduino.h>
#include <U8g2lib.h>
#include <WiFiNINA.h>
#include <ArduinoMqttClient.h>
#include <SPI.h>

#define SECRET_SSID "enter your wifi ssid here"
#define SECRET_PASS "enter your password here"
#define FLESPI_TOKEN "enter your flespi token here"
#define ANALOG_PORT  A2
```

```
#define MQTT_BROKER    "mqtt.flespi.io"
#define MQTT_PORT      1883

U8G2_ST7565_NHD_C12864_F_4W_SW_SPI u8g2(U8G2_R0, /* clock=*/
13, /* data=*/ 11, /* cs=*/ 10, /* dc=*/ 9, /* reset=*/ 8);
float capacitance;
WiFiClient wifiClient;
MqttClient mqttClient(wifiClient);

// checks connection to wifi network and flespi MQTT server
void check_connection()
{
  if (!mqttClient.connected()) {
    WiFi.end();
    WiFi.begin(SECRET_SSID, SECRET_PASS);
    delay(10000);
    mqttClient.setUsernamePassword(FLESPI_TOKEN, "");
    if (!mqttClient.connect(MQTT_BROKER, MQTT_PORT)) {
      Serial.print("MQTT connection failed! Error code = ");
      Serial.println(mqttClient.connectError());
      delay(100);
    }
  }
}

void setup() {
  pinMode(LED_BUILTIN, OUTPUT);
  pinMode(4, OUTPUT);
  Serial.begin(9600);
  analogReference(DEFAULT);
  check_connection();
}

void loop() {

  String moisture_string;
  check_connection();

  // read moisture sensor, since this is a wifiRev2 we need to
set the reference to VDD
  analogReference(VDD);
```

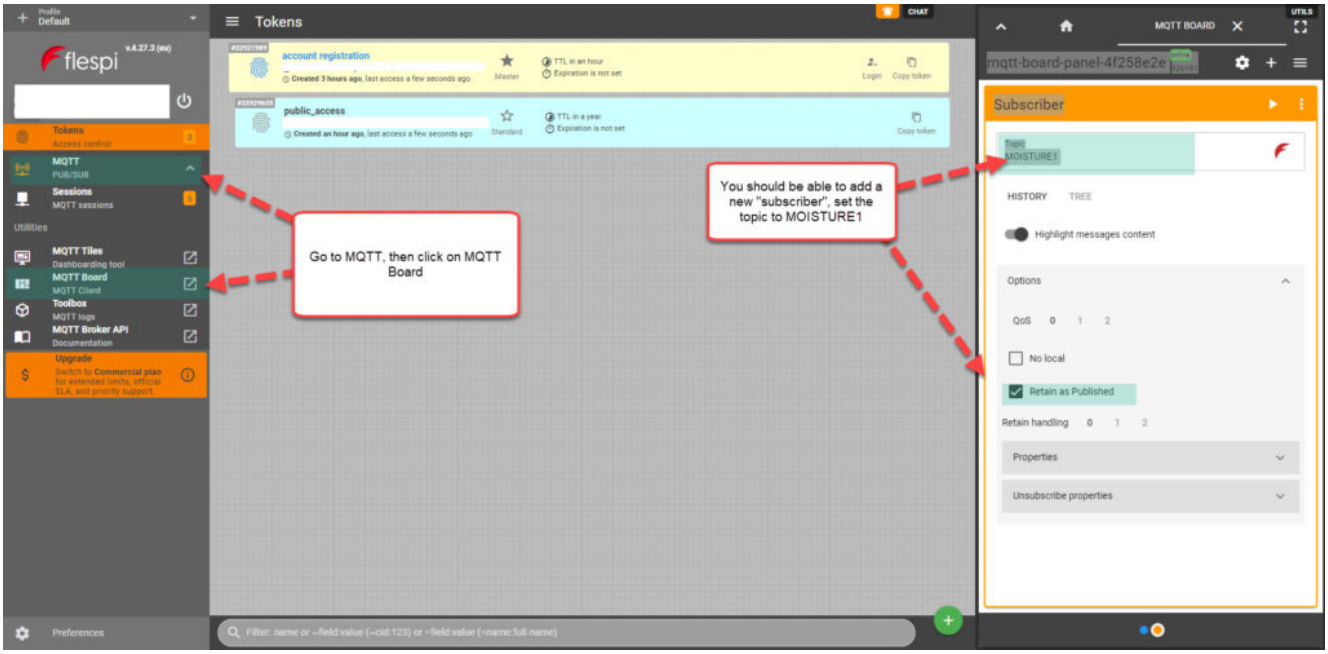
```
  capacitance = analogRead(ANALOG_PORT);
  // form the string we will display on the Arduino LCD screen
  moisture_string = String(capacitance) + " mV";
  Serial.println(moisture_string);
  // send moisture sensor reading to flespi
  mqttClient.beginMessage("MOISTURE1");
  mqttClient.print(capacitance);
  mqttClient.endMessage();

  // the LCD screen only works if I reinitialize it on every
loop
   // I also need to reset the analogReference for it to
properly work
  analogReference(DEFAULT);
  u8g2.begin();
  u8g2.setFont(u8g2_font_crox3h_tf);
  u8g2.clearBuffer();          // clear the internal memory
   u8g2.drawStr(10,15,moisture_string.c_str());   // write
something to the internal memory
  u8g2.sendBuffer();          // transfer internal memory to
the display

  delay(5000);
}
```

Your Arduino should now connect to the internet, take a reading from the moisture sensor, display it on the LCD shield and send it to flespi for recording. Note that the display of the data on the LCD shield is quite rudimentary. This is because I didn’t optimize the font or play too much with the interface. However, this code should provide you with a good template if you want to refine the display.

Configure Flespi

The next step is to configure flespi to record and display our readings. First, click the MQTT option to the left and then go into the “MQTT Board” (click the button, no the arrow that opens up a new page). Here, you will be able to add a new subscriber. A “subscriber” is an instance that listens to MQTT

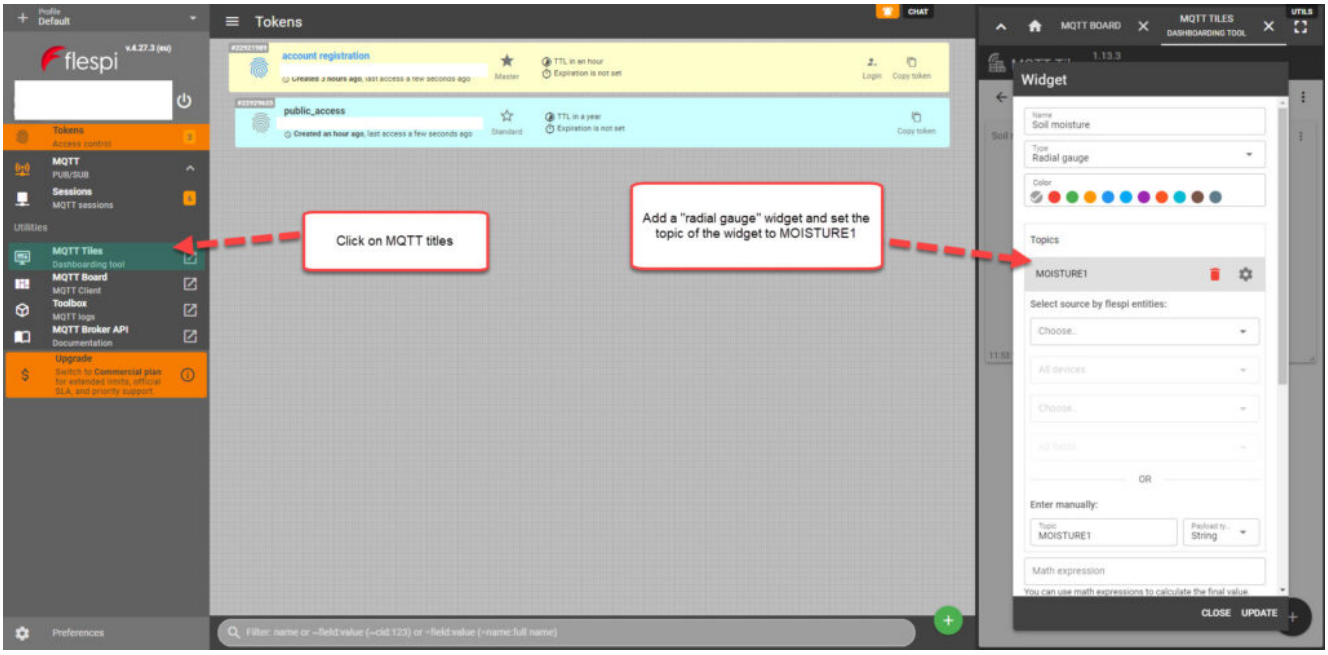
messages being published and “MOISTURE1” is the topic that our Arduino will be publishing messages to. If you want to publish data for multiple sensors, you should give each sensor its own topic, then add one flespi subscriber for each sensor.



Go to flespi and create a new “subscriber”, set the topic to MOISTURE1

Create the Dashboard

The last step, is to use the “MQTT Titles” menu to create a dashboard. I added a gauge widget to a new dashboard, and then set the topic of it to MOISTURE1, so that its data is updated with our MQTT messages. I set the minimum value to 200; the maximum value to 460; and the low, mid, and high levels to 250, 325, and 400 respectively.



Use the MQTT titles menu to add widgets to a new dashboard

After you finish creating the dashboard, you can then use the “Get link” button, which looks like a link from a chain next to your dashboard’s title. You will need to create an additional token in the “Tokens” menu so that you can use it for the sharing of the dashboard. After you generate the link, it should be publicly available for anyone who is interested. This is the link to the dashboard I created.

Conclusion

You can create a simple and expandable sensor station using an Arduino Wifi Rev2, a capacitive moisture sensor, and an LCD shield. This station can be connected to the internet via Wifi and send its data to flespi, which allows us to create free online dashboards. You can expand on this sensor station by adding more moisture sensors or any other Gravity shield compatible sensors, such as a BME280 sensor for temperature, humidity, and atmospheric pressure readings.

How to choose the best hydroponic bucket system for you

You can use simple buckets to create versatile hydroponic systems. You can create a system to grow a few plants at home or thousands of plants in a commercial facility. However, there are several types of bucket systems to choose from, and making the correct choice is vital to success. In this post, we are going to take a look at the different types of bucket systems. We will examine their pros and cons so that you can better understand them and choose the hydroponic bucket system that best suits your needs.

The Kratky bucket

The simplest system is the Kratky bucket system. In this setup, you have a bucket with one or several holes on the lid. You put plants in net pots with media and then fill the bucket with a nutrient solution so that it is barely touching the bottom of the media. The media initially draws water through capillary action, while the roots reach the nutrient solution. After that, the roots draw nutrients from the water and an air gap is created between the plant and the water as the crop evaporates water. The roots use this air gap to get the oxygen they need for respiration. For this reason, you don’t need any air pumps.

Kratky system using mason jars. I would advice to avoid transparent containers to reduce algae growth.

This completely passive system is easy to build and cheap. You only fill the bucket once with nutrient solution, and you don't need to check the pH, EC, or other variables through the crop cycle. However, this system requires careful determination of the bucket's volume, the nutrient solution concentrations, and the crops grown. You can read this post I wrote, for more tips to successfully grow using this bucket system.

However, you cannot easily grow large productive flowering plants in this system. This is because large plants consume too much water and nutrients throughout their life, and will require either a very big volume or complete changing of the nutrient solution at several points. For large flowering plants, it is more convenient to use other types of bucket systems that make solution changes easier. If you would like more information and data regarding the culture of large plants using Kratky hydroponics, please read this post.

The Kratky bucket system is ideal if you need a system with no power consumption, your environmental conditions don't have extremes, and you want to grow leafy greens or other small plants on a small scale. For larger scales, Kratky systems to grow leafy greens on rafts do exist, although large-scale

systems do involve pumps, at least to change solution between crop cycles.

The bucket with and air pump

The Kratky system has zero power consumption, but does require the grower to carefully manage the initial nutrient level and is not very tolerant to strong variations in environmental conditions. For this reason, a more robust method to grow is the bucket with an air stone. This is exactly the same as a Kratky system, except that air is constantly pumped into the nutrient solution and the nutrients are generally maintained at a specific level inside the bucket.

Constantly pumping air into the solution creates several advantages. The first is that air oxygenates the solution, which means the solution’s level is not critical. This is because plant roots have access to oxygen, even if more than the ideal percentage of the root mass is submerged in the solution. The second is that air will help regulate the temperature of the nutrient solution. As air bubbles through and evaporates water, it helps keep the solution cool. Kratky systems can suffer from unwanted temperature spikes if the air temperature gets too hot. This is a common reason for disease and failure in Kratky systems.

A typical air-pump bucket system growing kit

Systems with an air pump are usually easier for people who are just starting. The low cost and low failure rates are the main reason why this is a very popular choice for first-time hydroponic enthusiasts. However, since water evaporates more, there is a need to at least replenish water through the crop cycle. You are also limited to smaller plants unless you're willing to fully change the nutrient solution several times per crop cycle, which is inconvenient with a bucket system like this. It is also uncommon to see systems like this on a larger scale, as changing and cleaning hundreds of buckets manually and having hundreds of airlines going into buckets is not practical.

Note that air pumps bring substantial amounts of algae into solutions that will thrive if any light can get into your buckets. For hydroponic systems that use air pumps, make sure

you use buckets made of black plastic so that no light gets in. White plastic will allow too much light to get in and algae will proliferate.

You can buy several ready-made hydroponic systems of this type. For example this one or this one for multiple small plants.

The Dutch bucket system

A Dutch bucket system is great to grow large plants. In this setup, buckets are connected to drain lines at the bottom. This allows you to pump the nutrient solution into the buckets and allow it to drain several times per day. The constant cycling of solution exposes roots to large amounts of oxygen between irrigation cycles, making this a great setup for highly productive crops.

The Dutch bucket system is therefore an active system, requiring water pumps to keep the plants alive. This dramatically increases the energy consumption needs of the crop and makes the pumps and timers fundamental components of the hydroponic system. An active bucket system like this will usually give the grower 12-24 hours, depending on conditions, to fix critical components in case of failure before plants start to suffer irreversible damage. To prevent damage in commercial operations, drains will usually allow for some amount of water to remain at the bottom of the buckets so that large plants have a buffer to survive more prolonged technical issues.

A commercial Dutch bucket hydroponic system

The need to support the plants without water also means you need to use a lot more media, as the bucket themselves need to be filled with it. Since multiple flood and drain cycles are desirable this also means that the media needs to dry back relatively quickly, reason why media like rice husks, perlite or expanded clay, are used. Media costs of Dutch bucket systems are significantly larger than those of other systems because of this. You can run Dutch bucket systems with netpots as well, but this tends to make the system much less robust to pump failure.

Dutch bucket systems are a good choice if you want to grow highly productive large plants. They offer more robustness when compared with NFT systems – which have more critical points of failure – and the large amount of media provides a good temperature buffer and a great anchoring point for large plants. Several small-scale kits to grow using Dutch buckets also exist (see this one for example). However, they take significantly more space than the alternatives we described before. They require access to power and space for pumps, a large nutrient reservoir, and the supporting infrastructure for the plants. They also require nutrient solution management skills.

Conclusion

Bucket systems are very popular in hydroponics. They can be as simple as a bucket with a hole and a net pot or as complex as Dutch bucket systems with interconnected drain systems and full nutrient solution recirculation.

The easiest system to start with is a hydroponic bucket system with an air pump, as this eliminates the need to gauge the container volume and nutrient level precisely and allows for healthier growth, fewer disease issues, and easier temperature control.

A Kratky system can be great to grow small plants at a low cost with no power, but some experimentation with the nutrient level and concentration is usually required to get a satisfactory crop.

For large plants, the Dutch bucket system is a great choice, if you have the space and power availability. Dutch bucket kits for small-scale growers are also readily available.

Have you ever grown using buckets? Which type of system have you used and why? Let us know in the comments below!