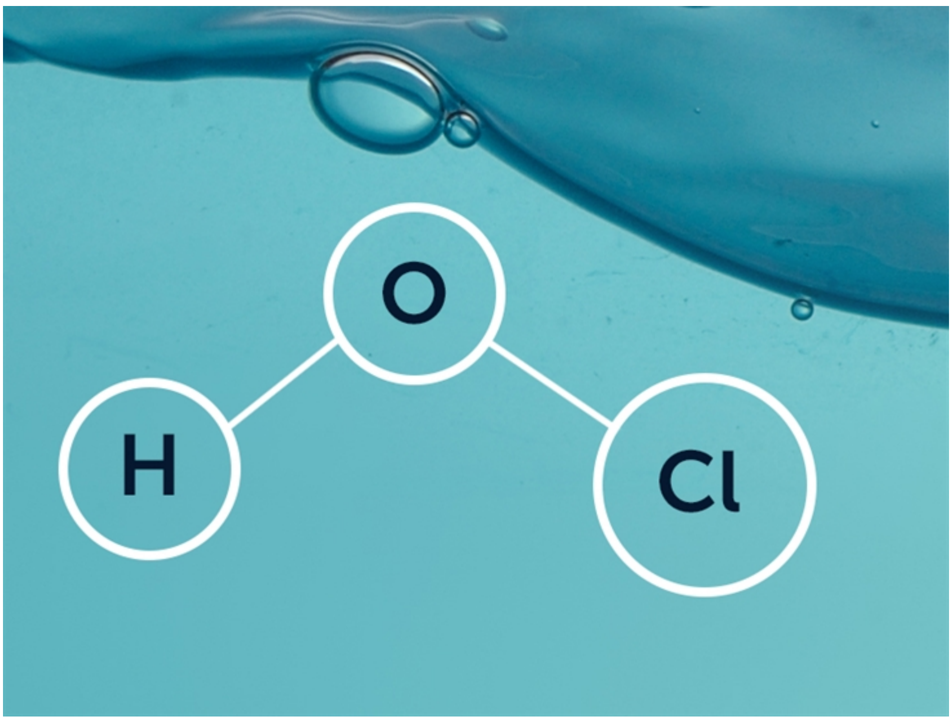
How to prepare your own hypochlorous acid cleaner using bleach

During the past couple of years, cleaning products based on hypochlorous acid derived from electrolysis have become popular in the hydroponic industry. This is because, in the USA – per 40 CFR § 180.940 – hypochlorous acid products containing less than 200 ppm of active chlorine are exempted from many manufacturing and handling requirements and are therefore easy to produce and dispense to hydroponic growers. While more dilute, the formulations produced can often be much more stable than more concentrated products and still provide satisfactory cleaning results in a hydroponic reservoir. However, the products carry a lot of additional cost compared to traditional sodium hypochlorite based cleaning products. This is because more needs to be used – as they are more dilute – and the products themselves are often much more expensive.



Graphic representation of hypochlorous acid

In this post, I want to help you create a solution analogous to many commercially available, electrolytically derived hypochlorous acid cleaners, using products that are easily available and low cost. The resulting solution is – for all intents and purposes I can think of – equivalent to electrochemically derived hypochlorous acid, since the hypochlorite ion becomes protonated at low pH, generating the required substance during the preparation process. To create this formulation, I relied on the following documents and the scientific literature they referenced (1, 2, 3).

Important note. *Hypochlorous acid is unstable in highly concentrated solutions. Increasing the concentration of the formulation below significantly can lead to potentially dangerous releases of chlorine gas when the pH is lowered. Work in a well ventilated area and do not exceed the concentration amounts recommended in this preparation. Work responsibly and make sure to read all the MSDS of the substances used and use appropriate personal protection equipment.*

These are the things you will need for the preparation :

1. Freshly bought Clorox (7.4%). The solution should not be older than one week.
2. A 20 mL syringe.
3. Monopotassium Phosphate (MKP).
4. Sodium Chloride (table salt will do).
5. Magnesium Sulfate.
6. Sodium Tripolyphosphate.
7. A calibrated pH meter.
8. A scale to weigh salts, +/-0.1g.
9. A scale to weigh water +/-0.1kg
10. Distilled or RO water (tap water will not work). Distilled is preferable.
11. Clean plastic, air-tight container (at least 1gal) to store the resulting solution. The container should be

opaque.

This is the procedure you should follow for the preparation of the hypochlorous acid solution (values for ~1.2 gallon, can be scaled up for larger amounts):

1. Calibrate your pH meter using fresh pH 4 and pH 7 buffer solutions.
2. Fill the container with 3.6 kg of distilled water, this will be referred to as the solution.
3. Weigh and add 0.5g of Sodium Chloride to the solution.
4. Stir until fully mixed.
5. Weigh and add 0.1g of Sodium tripolyphosphate to the solution.
6. Stir until fully mixed.
7. Measure 11mL of Clorox and add it to the solution. If you’re working with a bleach solution with concentration other than 7.4%, multiply 11mL by 7.4 and divide by your concentration to obtain the amount you should use in mL (for example, if using a 6% bleach solution, you would require 11*7.4/6 = 13.56mL).
8. Stir until fully mixed.
9. Weigh 0.5g of Monopotassium phosphate and add to the solution.
10. Stir until fully mixed.
11. Measure the pH of the mix. If the pH is >7 slowly add and fully mix small portions (~0.1g) of monopotassium phosphate until the pH is in the 6.5-7 range. Take at least 1 minute between additions to ensure the pH has stabilized before adding more.
12. Weigh and add 3.5g of Magnesium sulfate to the solution
13. Stir until fully mixed.
14. Add 0.9kg of water.
15. Confirm final pH is in the 6-7 range, you can add more monopotassium phosphate if needed to drop the pH.

This should provide you with a solution that is stable in the medium term and has the active chlorine concentration of a formulation similar to products like Athena Cleanse. The expected concentration of hypochlorous acid should be around 0.02% (200ppm). It can be used from 2 to 10mL/gal of hydroponic nutrient solution, depending on the severity of the problems that need to be solved. *For overall maintenance and the solution of minor infections, dosages of 5mL/gal should be more than adequate*. The Magnesium Sulfate and Sodium Chloride are added as stabilizing agents, while the mono potassium phosphate is added as a pH buffering agent and the sodium tripolyphosphate is a cleaning agent meant to keep irrigation lines clean (it can be omitted if this is not a concern). *Note that the contributions of the mineral ions to a formulations nutrition at the applied concentrations are negligible.*

Please do let me know if you have any questions about the above preparation. **If you have prepared it, please let us know how it went in the comments below!**

A guide to different pH up options in hydroponics

When is pH up needed?

The control of pH in hydroponics is critical. Most commonly, we need to decrease the pH of our solutions as most nutrients will initially be at a higher than desired pH. This is especially true when tap water or silicates are used, as both of these inputs will increase the overall pH of hydroponic nutrients after they are prepared. In recirculating systems, pH will also tend to drift up due to the charge imbalance created by the high active uptake of nitrate ions carried out by most plant species. For a discussion on pH down options, please read my previous post on this topic.

However, there are certain circumstances where the pH of hydroponic solutions needs to be increased. This can happen when tap water or silicates are not used or when plants decrease pH due to an aggressive uptake of some cations. Plants like tomatoes can do this when grown in solutions with high potassium contributions, as they will actively uptake these nutrients to the point of changing pH balance. Excess ammonium can be another common cause for pH decreases in hydroponic solutions that require the use of pH up solutions.

Potassium hydroxide pellets, the most powerful pH up option available to growers

With this in mind, let’s discuss the pH up options that are available in hydroponics. I only considered substances that are soluble enough to create concentrated solutions, such that they can be used with injector systems.

pH up options

Sodium or potassium hydroxide (NaOH, KOH)

These are the strongest. They are low cost, can be used to prepare highly concentrated solutions and will increase the pH most effectively. They are however unstable as a function of time because they react with carbon dioxide from the air to form sodium or potassium carbonates. This means that their concentrated solutions need to be kept in airtight containers and that their basic power will decrease with time if this is not the case. Additionally, these hydroxides are extremely corrosive and their powder is an important health hazard. Dissolving them in water also generates very large amounts of heat – sometimes even boiling the water – which makes their usage more dangerous. Although desirable when basic power is the most important short term concern, I recommend to avoid them giving their PPE requirements and the lack of long term stability.

When these hydroxides are used, potassium hydroxide is the recommended form, as potassium hydroxide is both more basic and a plant nutrient, while excess sodium can cause problems with plant development. However, sodium hydroxide might be more desirable if it can be obtained at a particularly low price and small additions of sodium are not a concern.

Potassium silicate

This is a soluble form of silicon that is stable at high pH values. While solutions of potassium silicate by itself can be prepared and used as a pH up option, it is usually stabilized with a small addition of potassium hydroxide to take the pH of solutions to the 11-12 range. Potassium silicate contributes both potassium and silicon to hydroponic solutions – both important nutrients – and its use can be more beneficial than the use of pure potassium hydroxide. While silicates are less basic and more mass is required for the same pH buffering effect, the preparation and handling can often be much simpler than those of potassium hydroxide.

Note that potassium silicate solutions are also unstable when left in open air, as they will also react with atmospheric carbon dioxide to generate potassium carbonate. It is also worth noting that not all potassium silicates are the same, when looking for a highly soluble potassium silicate for hydroponics, make sure you get potassium silicates that have higher K/Si ratios. Usually ratios of at least 1.05 are required (make sure you convert both K and Si to their elemental forms, as most of these products report K as K_2O and Si as SiO_2).

Potassium carbonate (K_2CO_3)

This basic salt is stable in air, has less demanding PPE requirements and can also be used to prepare concentrated solutions (more than 1g of potassium carbonate can be dissolved per mL of water). Because of its lower basicity compared to potassium hydroxide, more of it also needs to be used to increase the pH of a hydroponic solution. However, solutions of it are stable, so there is no concern for their stability or changes to its basic power.

Another advantage given by potassium carbonate is that – contrary to the previous two examples – it does increase the buffering capacity of the solution against pH increases, due to the addition of carbonate to the solution. As carbon dioxide is lost to the air at the pH used in hydroponics, the pH of the solutions tends to drift up, this means that the carbonate addition makes the pH more stable in solutions where the pH is being constantly pushed down. This is all part of the carbonic acid/bicarbonate equilibrium, which also helps chemically buffer the solutions at the pH used in hydroponics.

Overall potassium carbonate is one of my favorite choices when there is a downward drift of pH in recirculating solutions.

Potassium phosphate (K_3PO_4)

Another weak base, potassium phosphate, can be used to prepare concentrated solutions and increase the pH in hydroponic solutions. While its solubility and basicity are lower than that of potassium carbonate, it does provide additional phosphorus that can buffer the pH of the solution. This happens because mono and dibasic phosphate ions are anions that be taken up by plants, therefore decreasing the pH. While phosphates can help chemically buffer the hydroponic solution against pH increases, for decreases the phosphate buffer is ineffective as the pKa of the relevant equilibrium is 7.2.

An issue with potassium phosphate is that it provides large contributions of K to solution. These potassium additions can be quite counter productive if the cause of the pH drift towards the downside is related to potassium uptake.

Potassium Citrate/Lactate/Acetate

Basic organic salts of potassium can also be used to increase the pH. These are all much weaker than even the carbonate and phosphate bases mentioned above and relatively large additions are required for even a moderate immediate effect in pH. However, since these anions are actively taken up by microbes, the microbial metabolism of these ions will create a longer term effect on pH. A moderate addition of potassium citrate can only cause a small increase of pH in the short term, with a larger increase happening during the following 24 hours.

A disadvantage is that these anions can also lead to explosions in bad microbe populations if the environment does not have an adequate microbial population. When these salts are used, adequate microbial inoculations need to be carried out to ensure that the microbes that will proliferate will not be pathogenic in nature.

Protein Hydrolysates

While hydrolysates themselves can have an acidic pH when put in solution, their microbial metabolism aggressively increases the pH of solutions in the medium term. This means that these hydrolysates should not be used for immediate pH adjusting, as they will tend to decrease pH further in the very short term, but they can be used as a more long term management option.

As with the above organic salts, their use also requires the presence of adequate microbial life. If you neglect to properly inoculate the media before their addition, then pathogens can also make use of these amino acids to proliferate.

Combinations are also possible

As with the case of pH down options, some of the best solutions for a problem come when several of the above solutions are combined. For example the use of potassium rich pH up solutions in microbe containing soilless media can often cause pH drift issues related with potassium to worsen. For this reason, it can be desirable in these cases to prepare pH up solutions that include protein. This means that you reduce the pH fast but then you have a residual effect from protein metabolism that helps you fight the pH increase as a function of time.

However not all pH up drifts are caused by potassium, as in the case of plants where pH up drift happens due to low nitrate uptake (for example some flowering plants that stop producing a lot of additional leaves during their flowering stage). In these cases potassium based pH up solutions cause no additional issues and combinations of potassium carbonate and potassium phosphate might be best.

Choose according to your goals

As in most cases, the best solution will depend on your circumstances. Think about whether you're just adjusting the pH of your initial solutions or whether you need to compensate for a constant drift, whether microbial life is present and whether you're concerned with the accumulation of any substances in a recirculating solution. Once you consider these factors and review the above solutions, you should be able to find the pH up solution that is better suited to your particular needs.

Are you using a pH up? Let us know why and which one you're using 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):

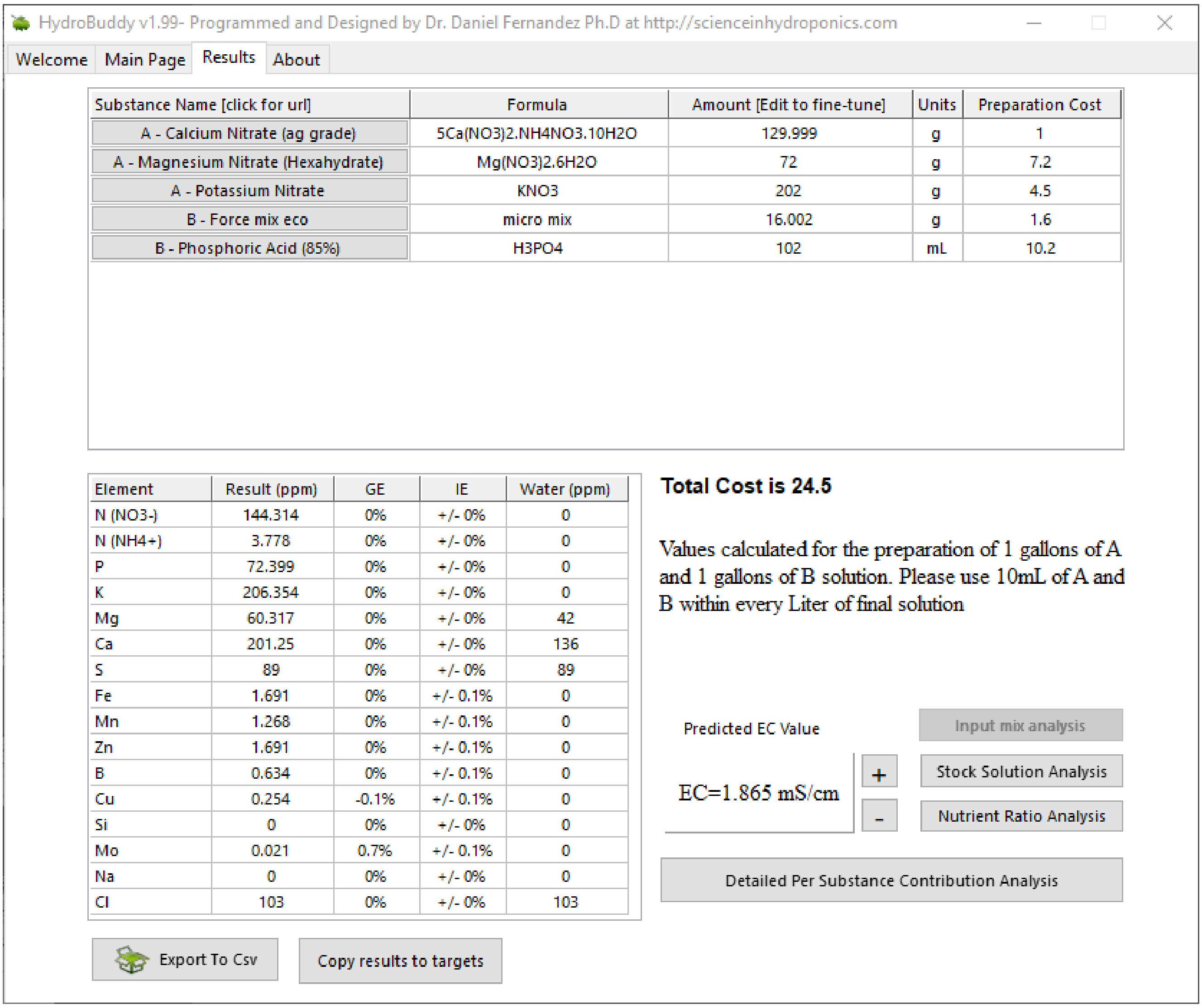
Name	Value	Unit
Calcium	136	ppm
Magnesium	42	ppm
Chloride	103	ppm
Sulfur	89	ppm
pH	7.6	
Alkalinity	240	mg/L of $CaCO_3$

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.



Substance Name [click for url]	Formula	Amount [Edit to fine-tune]	Units	Preparation Cost
A - Calcium Nitrate (ag grade)	5Ca(NO3)2.NH4NO3.10H2O	129.999	g	1
A - Magnesium Nitrate (Hexahydrate)	Mg(NO3)2.6H2O	72	g	7.2
A - Potassium Nitrate	KNO3	202	g	4.5
B - Force mix eco	micro mix	16.002	g	1.6
B - Phosphoric Acid (85%)	H3PO4	102	mL	10.2

Element	Result (ppm)	GE	IE	Water (ppm)
N (NO3-)	144.314	0%	+/- 0%	0
N (NH4+)	3.778	0%	+/- 0%	0
P	72.399	0%	+/- 0%	0
K	206.354	0%	+/- 0%	0
Mg	60.317	0%	+/- 0%	42
Ca	201.25	0%	+/- 0%	136
S	89	0%	+/- 0%	89
Fe	1.691	0%	+/- 0.1%	0
Mn	1.268	0%	+/- 0.1%	0
Zn	1.691	0%	+/- 0.1%	0
B	0.634	0%	+/- 0.1%	0
Cu	0.254	-0.1%	+/- 0.1%	0
Si	0	0%	+/- 0%	0
Mo	0.021	0.7%	+/- 0.1%	0
Na	0	0%	+/- 0%	0
Cl	103	0%	+/- 0%	103

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?

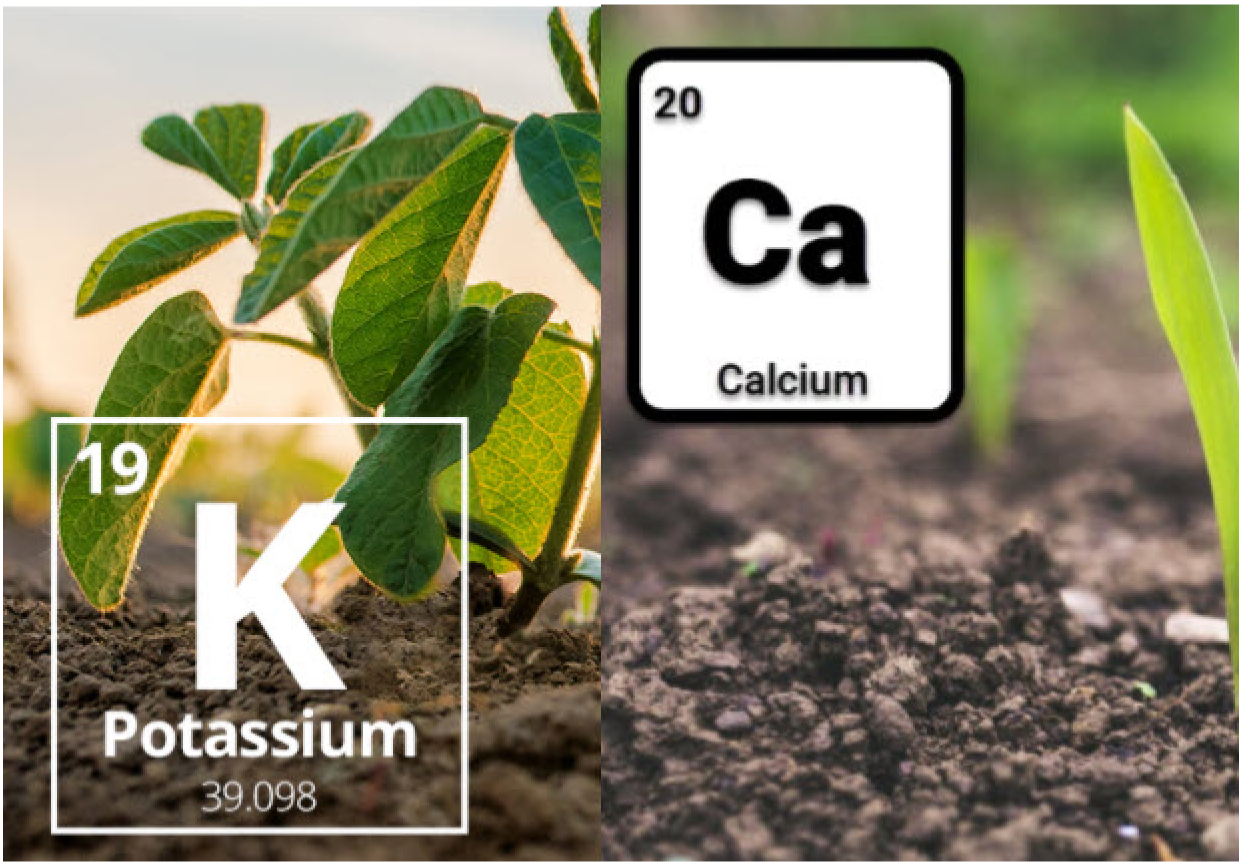
I have experimentally prepared the above concentrated solution – which yields a completely transparent solution – and have created hydroponic solutions I am now using to feed my home garden plants. After adding to my tap water – initial pH of 7.6 – I end up with a solution at a pH of 5.6-5.8 with around 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!

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 ($dS\ m^{-1}$)	K:Ca	YFEL-wk 3 K	YFEL-wk 3 Ca	YFEL-wk 3 Mg	YFEL-wk 3 P	3YL wk 2 K	3YL wk 3 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.

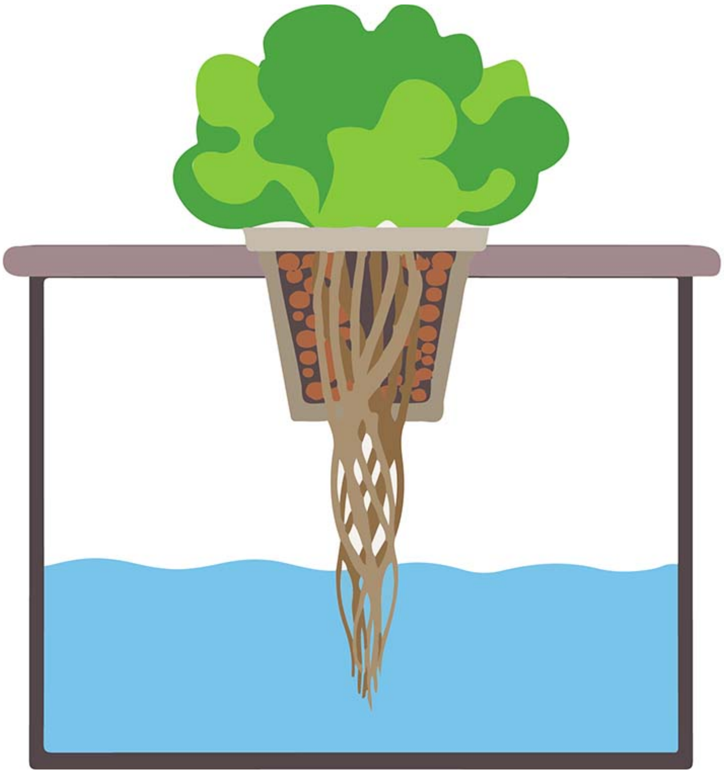
In the first category of products, we have things like mined magnesium sulfate, potassium sulfate, rock phosphate, sodium nitrate, or limestone. In the second category, we have things like fish emulsion, kelp extract, blood meal, and bone meal, while in the third category we have products like the Biomin 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 solution]()s, 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.

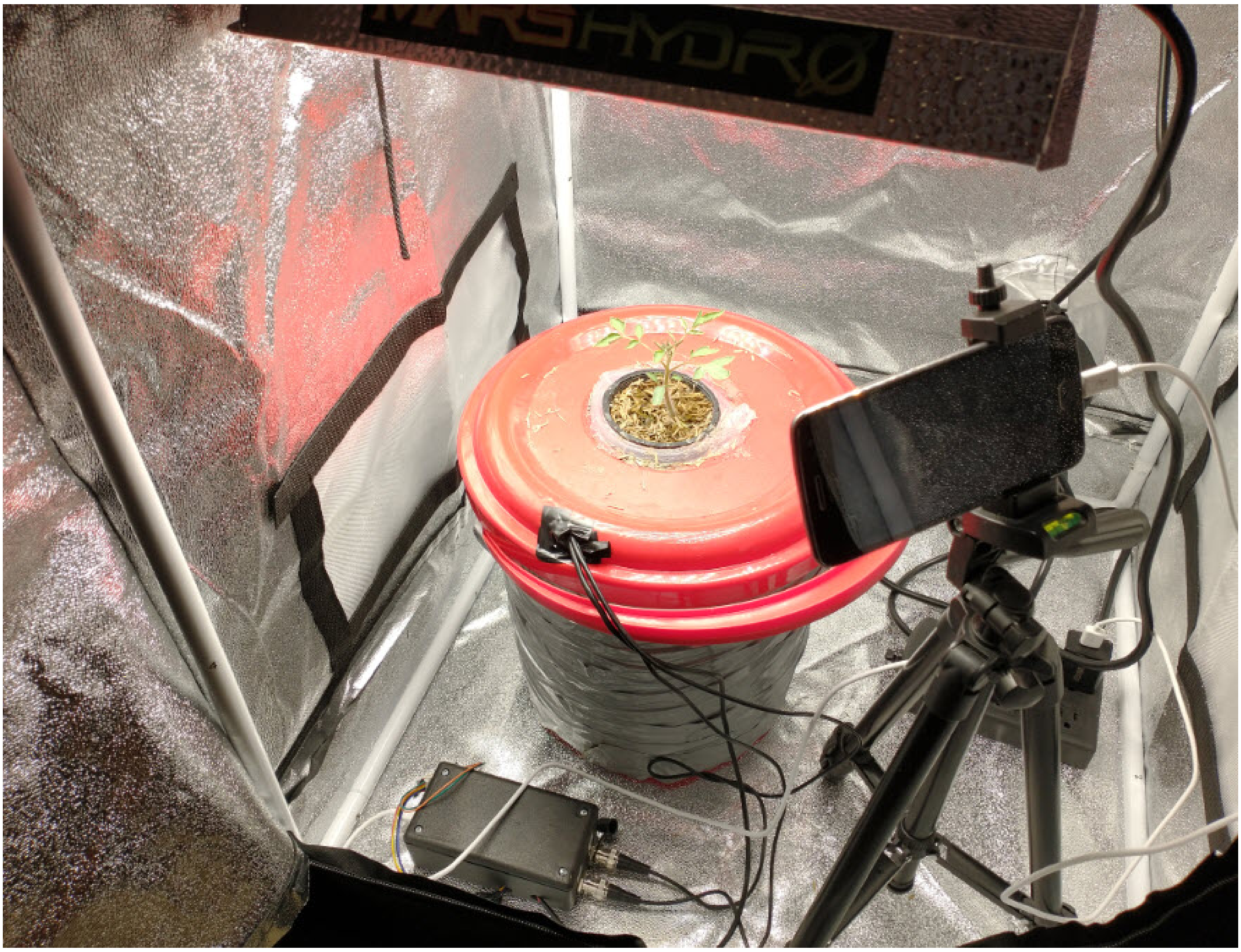
Introduction video for this Kratky project.

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

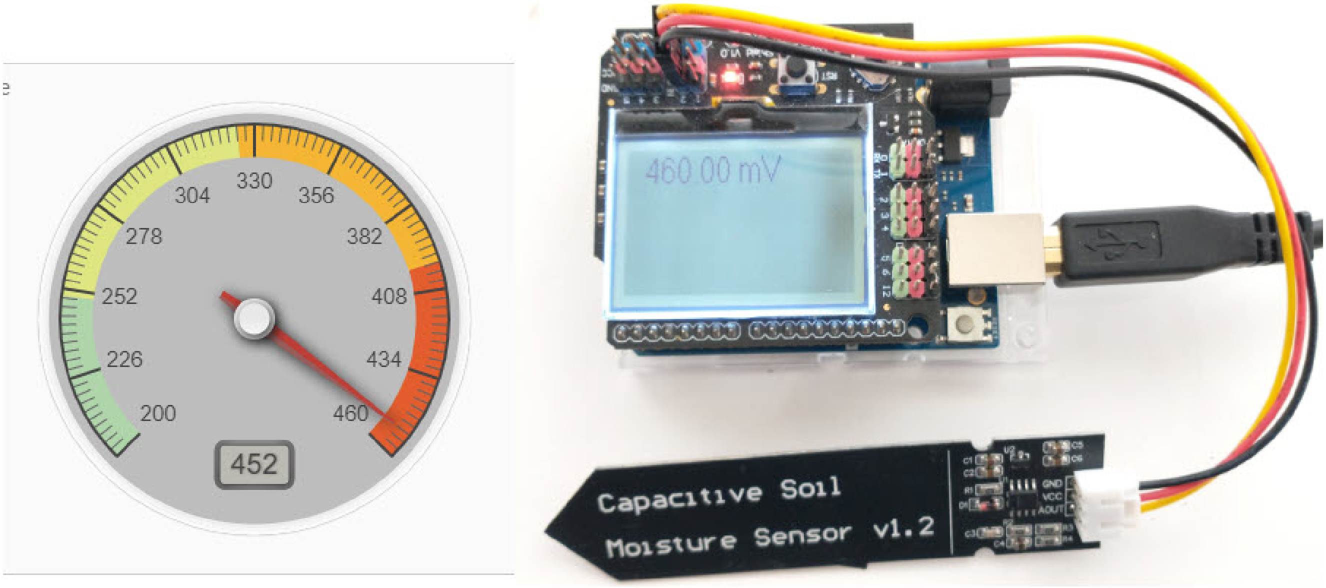
I have started a new project where I will fully record the complete development process of a large flowering plant in a Kratky setup. We will have information about the EC and pH changes of the solution, as well as information about how different nutrient concentrations (N, K and Ca) change through the 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!

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.**



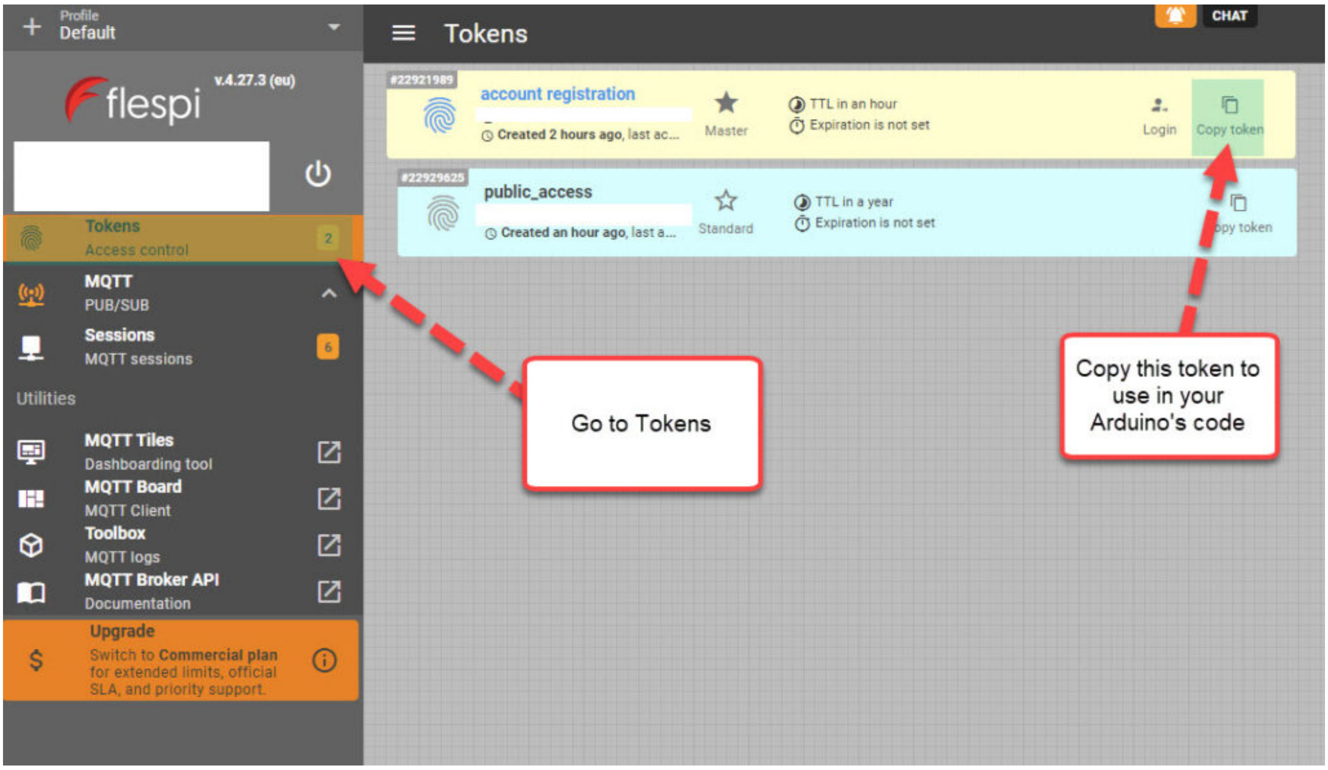
An Arduino Wifi Rev2 connected to a moisture sensor, transmitting readings to an MQTT server hosted by flespi that generates an online dashboard

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
```

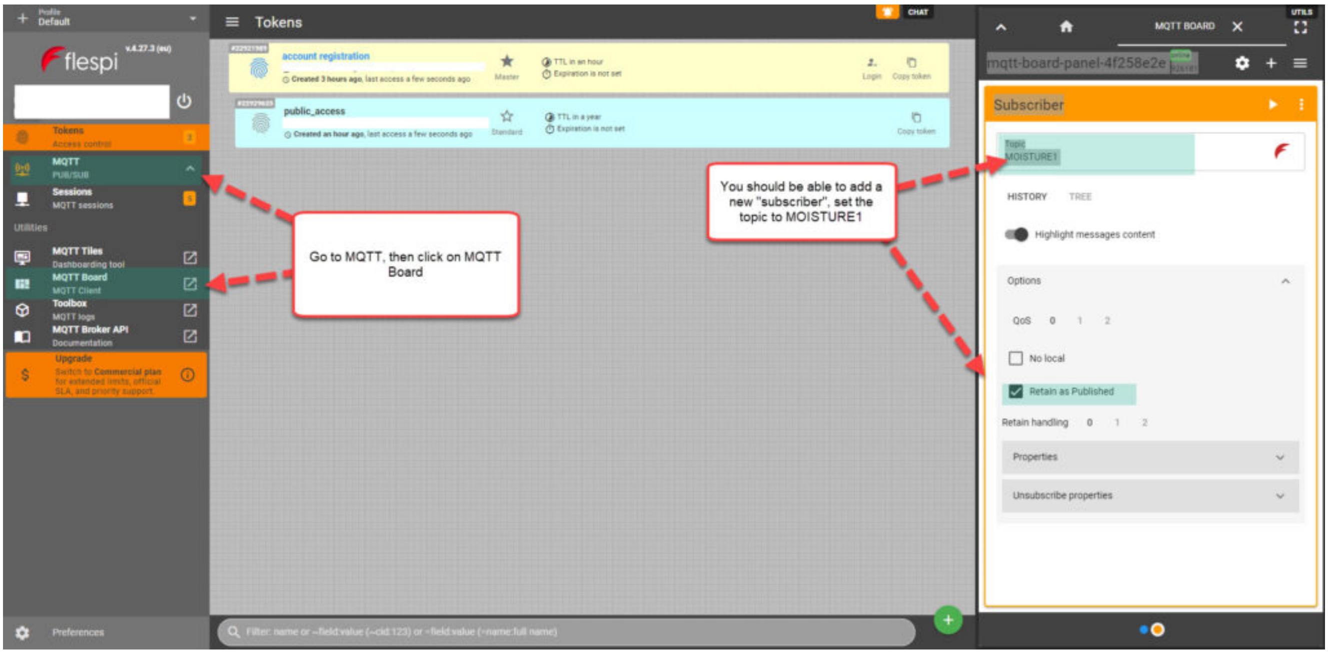
```
#define MQTT_BROKER    "mqtt.flespi.io"
#define MQTT_PORT      1883

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

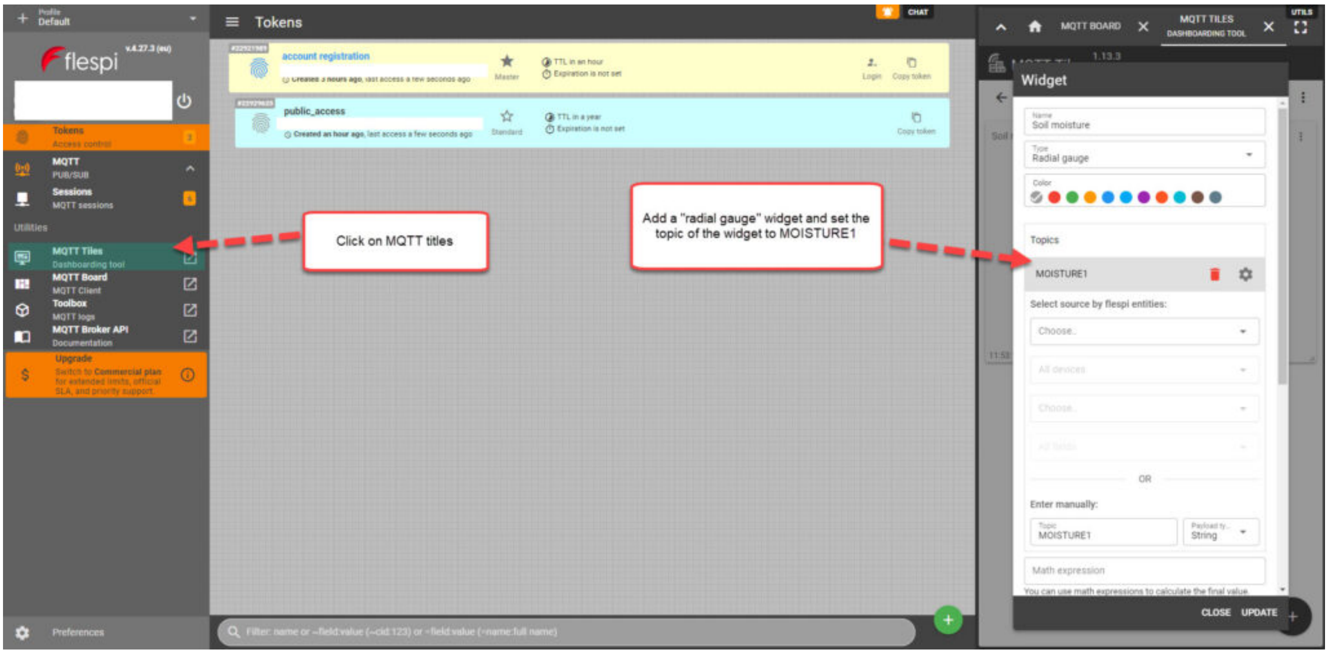
The next step is to configure flespi to record and display our readings. First, click the MQTT option to the left and then go into the “MQTT Board” (click the button, no the arrow that opens up a new page). Here, you will be able to add a new subscriber. A “subscriber” is an instance that listens to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

Arduino hydroponics, how to go from simple to complex

Hydroponic systems offer a great opportunity for DIY electronics. In these systems, you can monitor many variables, gather a lot of data, and build automated control systems using this information. However, the more advanced projects can be very overwhelming for people new to Arduinos and the simpler projects can be very limiting and hard to expand on if you don't make the right decisions from the start. In this post, I'm going to talk about the easiest way to start in Arduino hydroponics, which materials and boards to buy, and how to take this initial setup to a more complex approach with time.

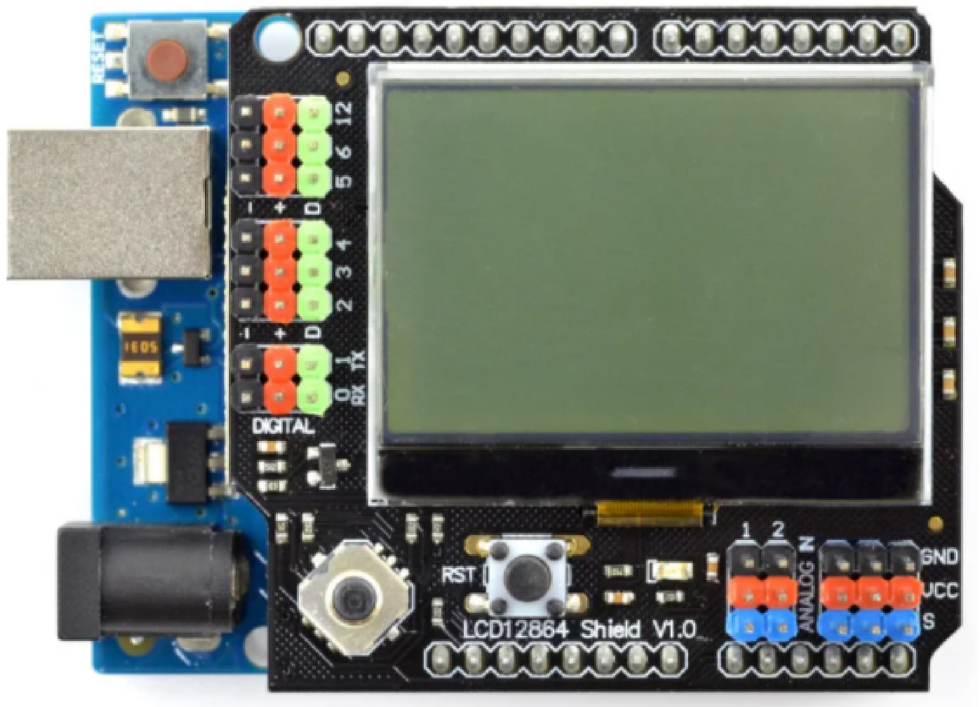
The Arduino Wifi Rev2

Buy the right Arduino

First, buy an Arduino that allows you to build simple projects without compromising your ability to upgrade in the future. My recommendation would be an Arduino Wifi Rev2. These are small boards that are compatible with Arduino Uno shields, with the ability to connect to your network when you're ready for more complex projects. Shields are boards that can be stacked on top of your Arduino, which allow you to get additional functionality or simplify the usage of the board. The Arduino Wifi Rev2 is a perfect choice, as you can outgrow simpler boards quickly while the more complicated ones are likely to be overkill and limit your potential shield choices.

Avoid soldering and protoboards, go for plug-and-play

For people new to Arduino, it is easier to avoid sensors that require soldering or protoboards and go with plug-and-play approaches. My all-time favorite is the “Gravity” system created by DFrobot, which uses shields that expose quick access connectors that you can use to plug-in sensors. My recommendation is the [LCD12864 Shield](), which has an LED and allows you to connect both analog and digital sensors. If you buy any “Gravity-compatible” sensor, you will only need to hook up a connector, no soldering or protoboards involved. You also have a graphic interface you can program and buttons you can use to interact with your Arduino and code.



The LCD12864 Gravity shield that exposes easy plug-and-play ports for sensors

Start with a temperature/humidity

display station

A good beginner project is to create a monitoring station that displays the readings from sensors on a screen. I've written about how to build such a station in a previous blog post. However, since pH and EC sensors can be more complicated, it is easier to start with temperature/humidity sensors only. There are several cheap sensors of this kind, such as the DHT11 and DHT22 sensors, but these have important issues. A better choice for hydroponics is the SHT1x sensor. If you are more advanced, the BME280 sensors are now my low-cost sensor of choice. There are lots of gravity sensors to choose from. You can also monitor CO_2, light intensity, solution temperature, EC, pH, and other variables as you become more advanced.

The SHT1x Gravity sensor, this can be easily plugged into the LCD12864 shield shown before

When you go into EC/pH monitoring, make sure you buy sensors that have electrically isolated boards. The ones from DFRobot are not electrically isolated and have important issues when multiple probes are put in the same solution. Most cheap ones on eBay/Amazon, have the same issues. I would recommend the sensors boards from uFire, which have a lower cost, are properly isolated, and are easy to use. The hydroponic kit collection, offers all the sensors and boards you require, in rugged industrial quality configurations, to build a hydroponic monitoring station.

Next step, simple control

The next step in complexity is control. You can use a Gravity relay to switch a light or timer on or off. You can also use a simple dead-band algorithm to attempt to control your temperature and humidity values by using relays to turn humidifiers, dehumidifiers, or AC systems on or off. If you want to control nutrients and pH, this is also where you would get shields to run stepper motors and the peristaltic pumps required to feed solutions into a tank. I've used this shield stacked under an LCD12864 for this purpose.

As an example of simple control, imagine your humidity is getting too high, so you install a dehumidifier to keep your humidity from climbing above 80%, you then create a line of code that sets the relay to "on" whenever the humidity gets higher than 80% and shuts it down whenever it drops below 75%. That way your crop's humidity increases to 80%, the dehumidifier kicks in, and then it shuts down when it reaches 75%. This allows the setup to climb back up for some time, avoiding the continuous triggering of your appliance.

Data Logging

After you're comfortable with both monitoring setups and simple control, the next step is data logging. Up to this point, none of your setups have done any data logging. By its very nature, an Arduino is not built to log any data, so this will require interactions with computers. My favorite way to do this is to set up a MyCodo server on a Raspberry Pi, then transmit data to it using the MQTT protocol. Since your Arduino Wifi v2 can connect to your Wifi network, you will be able to transmit data to your MyCodo using this configuration.

A sample of the data-logging capabilities of a MyCodo server. Taken from the MyCodo site.

I have previously written posts about MyCodo, as well as how to build a pH/EC wireless sensing station that transmits data to a MyCodo server. This allows me to log data continuously and monitor it without having to go into my hydroponic crop. Since the server is centralized, it also allows you to monitor multiple sensing stations simultaneously. I use my MyCodo server to monitor both my hydroponic crops and Arduino sensing stations that monitor how much food my cats eat.

More complex control

After you have connected your Arduino to a MyCodo server, you have access to much more complicated control, through the Raspberry Pi computer. You can then implement control algorithms in the MyCodo, then communicate with your Arduino, and trigger actions using MQTT messages. This means that you no longer need to code the control logic into your Arduino but you can do all the control in the raspberry Pi and just communicate the decisions made to the Arduino Wifi Rev2.

More complicated algorithms includes the use of proper PID algorithms for the control of humidity, temperature, pH and EC. It also includes the implementation of reinforcement learning algorithms and other advanced control methods that the Raspberry Pi can have the capacity to run.

Conclusion

Arduino in hydroponics does not need to be complex. Your first project can be a simple temperature/humidity monitoring setup and you can evolve to more complicated projects as your understanding and proficiency grow. If you select a powerful and feature-rich Arduino from the start, you can use the same controller through all your different projects. If you select shields that can make your life easier – such as the LCD12864 shield – and use a plug-and-play sensor interface, you can concentrate on building your setup and your code, rather than on soldering, getting connections right, and dealing with messy protoboard setups.

The road from a simple monitoring station to a fully fledged automated hydroponic setup is a long one, but you can walk it in small steps.

Have you used Arduinos in your hydroponic setup? Let us know about your experience in the comments below!