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.

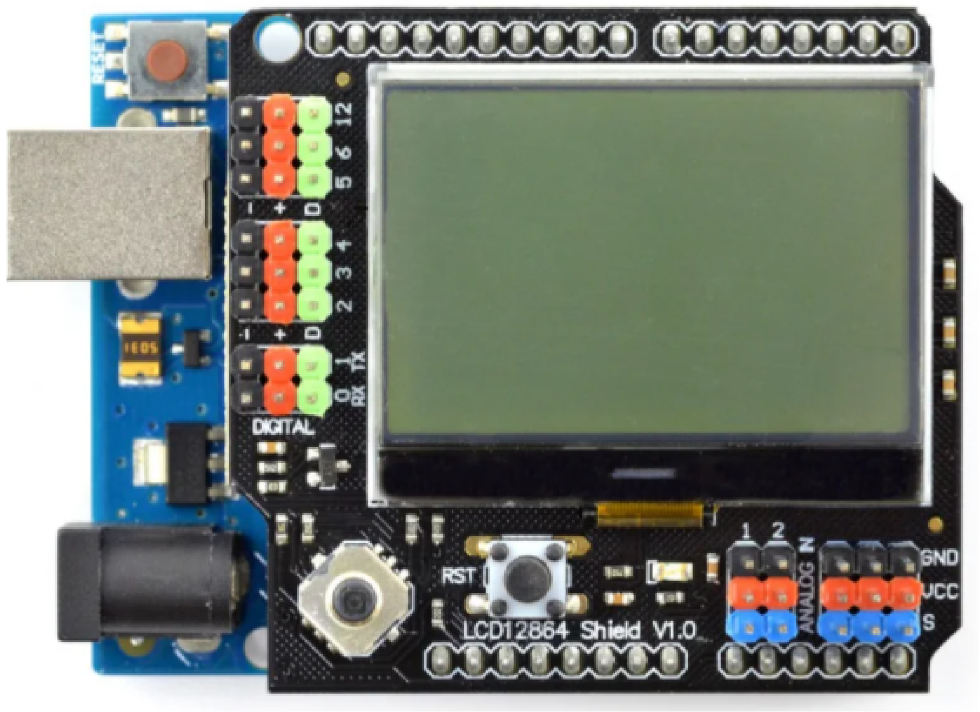
The Arduino Wifi Rev2

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

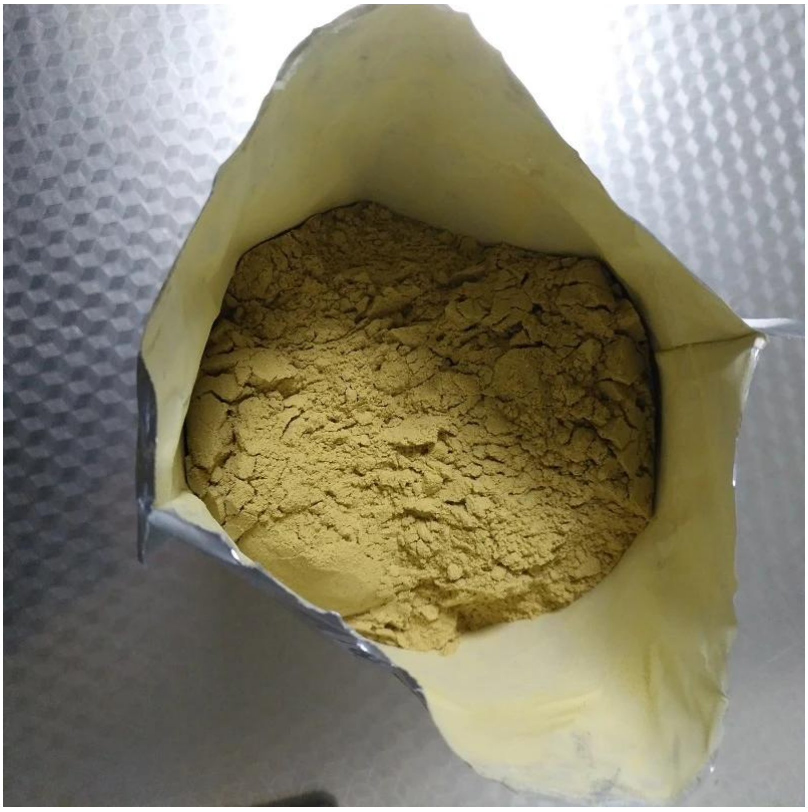
Arduino in hydroponics does not need to be complex. Your first project can be a simple temperature/humidity monitoring setup and you can evolve to more complicated projects as your understanding and proficiency grow. If you select a powerful and feature-rich Arduino from the start, you can use the same 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!

A great trick to higher chelate stability in hydroponics

The stability of micronutrients in hydroponic solution has been studied in depth during the last 5 decades (1). The EDTA molecule was the first cheap synthetic ligand that created highly stable chelates that could be used to stabilize heavy metals in solution. After this, efforts to create more stable chelates continued, with the introduction of HEDTA, DTPA, EDDHA, and other synthetic ligands. However, the stability of iron in solution still remains a problem. This is due to the chemistry of heavy metals in solution and the issues that arise as root zone chemical conditions change in a hydroponic crop. In this post we will discuss a simple trick, to increase the stability of the cheaply available iron EDTA chelate, the most commonly used in nutrient solutions. **Note, the term “heavy metal” in this post is used to refer to the transition metals used in hydroponics, mainly Fe, Zn, Mn and Cu.**



$Na_2FeEDTA$, one of the most commonly used Fe chelates in hydroponics.

Chelate stability

The stability of chelates is dominated by three competing forces. The first is the acid/base equilibrium of the ligand. Ligands like EDTA are only able to chelate Fe when their active sites are not occupied by hydrogen ions. As the pH goes down, these sites become occupied and the $EDTA^{-4}$ turns into $HEDTA^{-3}$, then H_2EDTA^{-2}, H_3EDTA^{-1}, and finally H_4EDTA. This process frees the heavy metal ions as the concentration of the active ligand ($EDTA^{-4}$) drops to near zero values. At very acidic pH values, the Fe^{2+} will effectively become fully unchelated due to this effect, although this does not happen to a very large extent at the pH values we see in hydroponics.

The second effect has to do with the affinity of the ligand for the heavy metal. This is what we call the “stability” of the chelate. It is measured through the use of the equilibrium constant of the reaction of the metal with the ligand. The larger this value, the bigger the stability of the chelate will be and the less free metal we will have in solution. For more information about this, you can read this previous post, where I share a table with a lot of stability constants for different ligands and heavy metals.

The third is the precipitation of free heavy metal ions by the formation of insoluble solids. This can be quite critical, as several of the solids that can form in hydroponics, mainly hydroxides, and phosphates, have very low solubility values. These can be compared by using the equilibrium constant of the solid with the ions in solution, what we call the Ksp in chemistry. The smaller the Ksp, the more insoluble a substance is. When these solids precipitate they take ions away from the solution and these are regenerated by the chelated heavy metal equilibrium reaction. This depletes the heavy metal slowly from the solution.

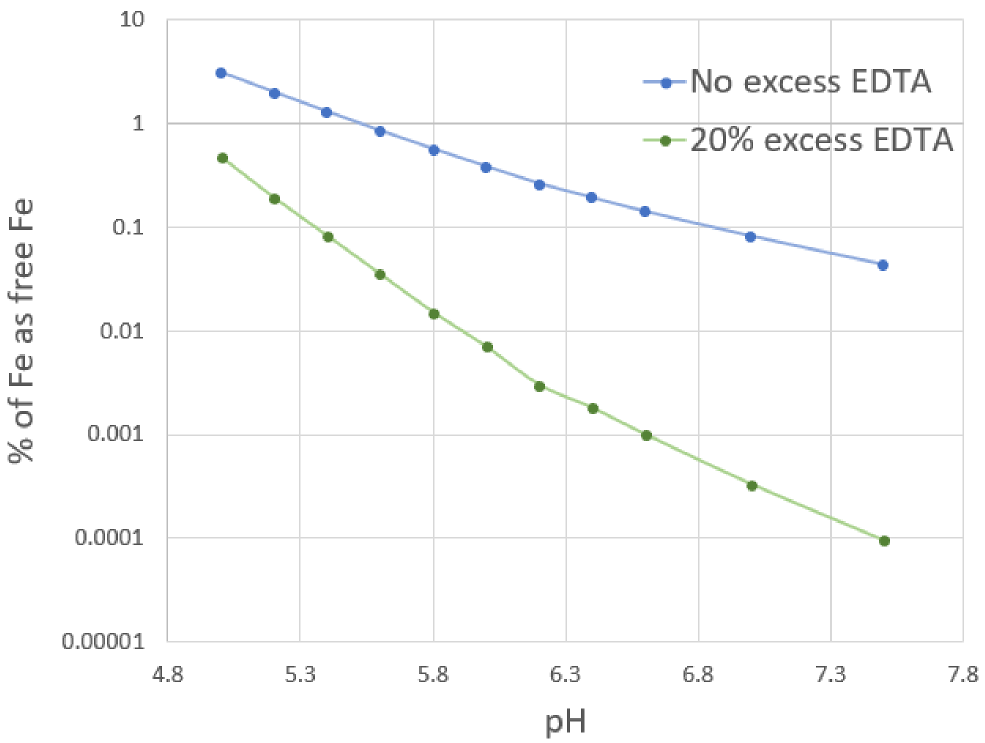
Free heavy metal ions

Since free heavy metal ions are the ones that can precipitate and become unavailable, what we desire is to lower the amount of free heavy metal ions in solution and increase the percent of chelated ions. Whenever you put a chelated heavy metal source in solution, like $Na_2FeEDTA$, the chelate goes into equilibrium with its unchelated form and all the acid/base species of the ligand's equilibrium reactions. This means that a percentage of the Fe becomes effectively unchelated. **In a solution where 1ppm of Fe from $Na_2FeEDTA$ is added, P is added at 30ppm and the pH is set to 6, around 0.38% of the Fe will be unchelated**.

As the pH increases the amount of free Fe actually decreases – as the acid/base equilibrium of the ligand shifts towards the base forms – but the concentration of other ions that can precipitate really insoluble salts, like phosphate or hydroxide, increases dramatically. At pH values above 7, even a small fraction of free Fe can lead to precipitation of some Fe salts. This is why iron EDTA chelates are not considered to be stable in basic pH, not because the chelate itself is unstable, but because there are even more stable Fe solids that can form and precipitate out the Fe.

A simple trick to alleviate the issue

Traditionally, the issue of having unchelated heavy metals has been approached by creating stronger chelates. DTPA, which has much higher stability constants, is able to generate much lower amounts of Fe, which leads to lower precipitation. The equilibrium constant with some isomers of EDDHA is actually so high, that no Fe solids are formed across almost the entire pH window in water. However, these chelates are more expensive, and – in the case of EDDHA – the presence of several different isomers complicates the situation.



Solution always has 1ppm of Fe added as $Na_2FeEDTA$ with 30ppm of P. The above was calculated using a system of equations accounting for all the EDTA and phosphate acid/base equilibria, as well as the heavy metal chelation.

A very simple trick to partially solve the problem is to add an excess of chelating agent into the hydroponic solution. If you're using EDTA, adding Na_2H_2EDTA on top of the heavy metal chelates can greatly help reduce the amount of free heavy metal in solution. This EDTA will also not remain unbound, as it will quickly chelate Mg and Ca in solution. These Ca and Mg chelates, will act as a reserve of ligand to ensure that almost all heavy metal ions are chelated. A 20% molar excess can generate dramatic results in the case of Fe^{2+}, as shown in the image above. This 20% "reserve" ligand, reduces the amount of free Fe by a factor of 10-100x, depending on the pH. Note that although the above slows down any precipitation reactions – as little free Fe is available – the hydroxide and phosphate ions will still win if the pH increases enough, as the stability constant of the Fe EDTA reaction remains the same.

To give a 20% excess of EDTA in molar terms, add 1.2mg/L of disodium EDTA to the final nutrient solution for every 1ppm of Fe. You can also add a 100% molar excess with no ill effects on plants, which will provide a more pronounced effect.

Conclusion

Adding a chelated heavy metal form to a hydroponic solution does not ensure that the metal will always be chelated. The chemical equilibria that exist with the free form of the heavy metal always happen and will always generate some percentage of free, unchelated metal. By adding an excess of the chelating agent, in this case, Na_2H_2EDTA, we can strongly displace the equilibrium and reduce the amount of free heavy metal present. The lower amount of heavy metal increases the pH stability window of the chelate and reduces the precipitation issues that happen as a consequence of free heavy metal ions being present in solution.

Do you add excess chelating agent to your nutrient solutions? Let us know about your experience in the comments!

Hydroponics vs soil, all you wanted to know

Hydroponics seeks to grow plants without soil. But is this any better? In this post, we are going to take a deep dive into the peer-reviewed literature comparing soil crops with hydroponic ones. We are going to look at papers that compare yields, quality, cost, and environmental impact. This will help us determine which growing method is better and under which circumstances. In this comparison, “hydroponics” encompasses any crop grown without soil, including those grown in soilless media.

Lettuce grown in a hydroponic and soil setup

How to compare

It can be hard to compare soilless and soil culture due to the many ways in which both can be done. Soil crops can be grown with or without fertilization, with or without irrigation restrictions, organically or with synthetic fertilizers, in a greenhouse or the field, etc. Different soils can also have widely different qualities and properties. Similarly, hydroponic crops use a wide variety of different systems and nutrient solutions. For this reason, I will focus my analysis on publications that try to directly compare products grown under both methods by the same researchers.

I will also look into literature reviews that try to describe the global picture. These articles can be important, as they can help us evaluate the impact of soil and soilless culture on a much larger scale. These can help us see the impact of all the different methods used and how tilting the scale one way might affect the big picture.

Quality

Many different studies have compared the quality of vegetables and fruits grown in hydroponic and soil cultures. The table below, shows you some of these studies and my assessment of the "winner" in each one, given their conclusions. I also analyzed these reviews on the matter (12, 13) that looked at the publications on the subject.

Ref	Product	Property	Winner
1	Lamb Lettuce	Shelf-life	soil
1	Lamb Lettuce	Quality	soil
2	Strawberry	Size	hydro
3	Lettuce	Nutrient density	hydro
4	Soybean	Nutrient density	hydro

5	Strawberry	Nutrient density	hydro
6	Strawberry	Nutrient density	hydro
6	Raspberry	Nutrient density	soil
7	Strawberry	Nutrient density & taste	hydro
7	Raspberry	Nutrient density & taste	hydro
8	Strawberry	Nutrient density	soil
9	Strawberry	Quality	soil
10	Cucumber	Quality	hydro
11	Pepper	Antioxidants	hydro
12	Pumpkin	Quality	hydro

Different studies comparing soil and hydroponic crops

The above results show us that, while hydroponics can produce better or equal results compared with soil, it is by no means guaranteed to do so. If the conditions of the hydroponic system are not adequately controlled or the soil is of much higher quality, the hydroponic system might perform worse.

Neither soil nor hydroponic systems are a guarantee of better or worse quality. It is false to assert that soil crops – even those grown organically, as in some of the above studies – can always provide better results compared to a hydroponic crop. Nutrient density, freshness, taste, and quality can be just as good or even better in a hydroponic system.

However, because of the larger control that the grower exerts in a hydroponic system, it is probably easier, on average, for an inexperienced grower to deliver better results in soil. This is because soil culture is more forgiving, and takes care of more aspects that a grower would have to directly control in a hydroponic system, such as root zone chemical conditions.

Yield

I would suggest reading this blog post I wrote about hydroponic yields first. In it, I talk about the issue of yield in hydroponics, and how the most frequently cited yields per acre – which come from a couple of books that do not properly cite their sources – cannot be assumed to be reliable. To compare with soil, we should therefore look at publications that have done their own experiments to compare both types of culture.

Yield, mean weight and number of total (T), marketable (M) and unmarketable (NM) fruits of zucchini plants grown on four substrates Values are the means of four replicate samples. In each column, values followed, by the same letter do not differ significantly at P = 0 05

	Yield			Fruit					
	(g/plant)			(g/fruit)			(No./plant)		
Substrate	T	M	NM	T	M	NM	T	M	NM
Cocofibre	2343[a]	2291[a]	55[b]	109.3[a]	113.9[a]	41.6[a]	21.3[a]	20.1[a]	1.2[c]
Perlite	2105[ab]	2030[a]	69[ab]	110.3[a]	115.7[a]	28.0[b]	19.8[a]	17.3[a]	2.5[ab]
Pumice	2178[ab]	2134[a]	51[b]	112.9[a]	118.9[a]	35 7[b]	19.3[a]	17.9[a]	1.4[bc]
Soil	1762[b]	1640[b]	123[a]	100.0[a]	116.3[a]	34.2[b]	17.6[a]	14.1[b]	3.5[a]

Yield comparison for zucchini grown under a variety of different soilless media and soil. Taken from here.

From the articles I reviewed on the subject, none of them gave soil the upper hand. All articles showed an increase in yield in terms of product produced per plant or area, to hydroponic growing (14, 15, 16, 17, 18). However, it was notably difficult to find articles comparing soil and soilless growing methods directly in terms of yield (as you can see I only found 5). This is likely because it is widely assumed that hydroponic crops always give larger yields per acre, so few bother to study this difference directly.

The magnitude of the yield differences is also interesting. Although the books described in my post about "hydroponic yields" cite differences greater than two orders of magnitude, the studies show differences that are always lower than one order of magnitude and most of the time below a 2x increase in yields. This means that, while hydroponic crops are more productive per area, to expect yield increases of 10x when going from soil to soilless culture is unreasonable. Depending on the crop, increases of only 20-30% might be reasonable.

It is also important to understand that higher yields are associated with more complicated hydroponic setups. For this reason, the largest reported yield increases might only be accessible through much larger capital investments.

Environmental impact

The environmental impact of hydroponic crops depends largely on how they handle nutrient solutions (18, 25). Open hydroponic systems will have significantly more water and fertilizer usage than closed systems. In closed systems, the type of system and the efforts made to treat and reuse nutrient solutions will play a key role in determining environmental impact (19, 20). With this in mind, an open hydroponic system is highly undesirable in terms of environmental impact. However, if you treat the runoff (22), this would be desirable over a soil system that uses synthetic fertilizers.

Note that the environmental impact of hydroponic systems increases dramatically if it uses artificial lights. If this is the case, a soil-based approach will always have a lower impact, unless renewable sources are used to produce the energy.

In the case of soil, environmental impact can be very different depending on the growing practices used. Organic growing approaches will deliver significantly lower impact compared to traditional soil agriculture, mainly due to the lower energy expenditure and because they avoid contamination of soil and aquifers with large amounts of nitrates and phosphates (21).

When considering environmental impact, it is also important to consider yields per area. While a closed hydroponic crop might have a higher environmental impact per acre of land used than an organic soil crop, if it produces 3x more product, the environmental impact per gram of fruit or vegetable produced might be much lower. Although I couldn’t find any direct studies comparing the environmental impact of soil and hydroponic approaches, it would be reasonable to think that a closed hydroponic system should have a lower environmental impact per gram of product, as long as the yields per area are significantly higher compared to the organic soil approach.

With that said, an approach that makes use of low energy inputs makes very efficient use of water, and has a high planting density, might be the ideal growing system in terms of environmental impact. I suggest you read my blog post about aquaponics if you're interested in this topic. Closed hydroponic systems that use treated sewage instead of newly prepared hydroponic nutrients might also be extremely low-impact, high-productivity systems (22, 26).

Cost

Money is important in agriculture, as it is often the main driver when determining the growing system. Hydroponic crops have higher startup costs compared with soil. This is because the minimal hydroponic setup is substantially more complex relative to the minimal soil setup. However, even when greenhouses are involved, the hydroponic setups will often have higher starting costs (23).

Although starting costs are higher, life cycle costs of hydroponic setups can be lower due to higher yields, fertilizer, and water use efficiency. This is especially the case when you grow highly efficient crops, like lettuce. In this study, (24) they compared the yield, cost, and water efficiency of different hydroponic and protected soil setups. Hydroponic NFT setups were much more water-efficient and much more feasible from an economic perspective.

Hydroponic crops also have access to areas that are traditionally unavailable for soil agriculture. For example, hydroponic crops can be grown on rooftops and produce significantly more money than solar panels under some conditions (25). In this case, hydroponic crops fill a niche that has no soil-based equivalent, since the area would never be used by soil agriculture.

Conclusion

The best soil grower is better than the worst hydroponic grower. The best hydroponic grower is better than the worst soil grower. The most important thing when you decide to grow a certain way, is to strive to do it in a manner that leads to higher quality, that maximizes yields, minimizes environmental impact and, if possible, is done at a low cost.

Soil agriculture has its place. It is cheaper to start with, requires fewer materials, can be done at a much larger scale, and can produce high-quality, sustainable results when done correctly. Hydroponic culture offers higher yields per area, potentially lower environmental impact, and lower life cycle costs. However, it costs more and requires substantially more knowledge and care to provide comparable results.

Have you grown in soil and hydroponics? Which one do you like best? Let us know in the comments below!

The best hydroponic medium you have never heard of

One of the most important choices in a soilless crop is the medium. Ideally, the media in a hydroponic crop should provide no nutrition but just act as support material for the plant. However, common media choices, such as coco coir and peat moss, are far from inert and their usage requires special modifications to the nutrient solutions in order to account for their specific chemical properties. In this post, I am going to talk about a great hydroponic medium choice that is fairly common in South American countries but rarely used in the United States or Canada.

Rice hulls, a key component of my favorite medium for soilless culture

Issues with existing media

The most commonly used hydroponic media types in the US are perlite, peat moss, coco coir, and rockwool. Peat moss tends to have higher than desirable water retention and acidifies strongly through time. For this reason, it is usually amended with perlite – to increase aeration – and with dolomite/limestone in order to buffer the constant increase in pH within the root zone. To maximize its potential, you need to account for these amendments and the natural evolution of peat moss through time in your nutrient solution or you will tend to have calcium, magnesium, and nitrogen uptake issues. All of which are commonly observed by peat moss growers.

Coco coir has other problems. It contains large amounts of chloride, sodium and potassium. It also decomposes through time and, in doing so, exposes cation exchange sites that strongly bind elements like calcium, magnesium and manganese. For this reason, you often need to either pretreat the coir with calcium containing solutions or adjust your nutrient solution chemistry to account for the evolution of the potassium release and calcium capture through the crop cycle. The concentrations and ratios of heavy metals also need to be changed to account for the affinity of the cation exchange sites for these ions.

Rockwool has better chemical and physical stability but the environmental impact of its production is high (1). It is also hard to reuse and its physical properties are hard to tune since it is hard to mix with other media effectively. Perlite, another rocky medium, is easy to reuse and has low environmental impact, but it dries back too quickly, which increases the need for energy for irrigation and dramatically increases the amount of waste generated in open (drain-to-waste) hydroponic systems.

Rice hulls, the first component of a better medium

Over the past 40 years, rice hull – also known as rice husk – has become a medium of choice in many countries due to its wide availability as an agricultural waste product. It is made primarily of silica structures supported by organic material, decomposes very slowly through time, and has very benign chemical properties. Rice hulls will not change pH through time, will slowly release bio-available silicon, and can be reused several times before they degrade. However, they usually contain insects and some rice, reason why sterilization of the media with hot water is usually required in order to avoid pest propagation and seedling death due to seed fermentation.

Another issue of rice hulls is their incredibly weak moisture retention. Rice husks are even worse than perlite at retaining water, reason why rice husks are commonly used as an amendment to increase aeration. A hydroponic crop using only rice husks as a medium is possible, provided that the crop is constantly irrigated to compensate for the very fast dry back period of the medium. This constant irrigation is achieved through drip systems.

Washed river sand, the perfect compliment

Given that rice hull is primarily made of silica and has excessively fast dry back, it would be ideally paired with a medium with similar chemical properties but opposite physical properties. River sand, which has exactly opposite physical properties and is also made primarily of silica, perfectly fits the bill. River sand has a very slow dry back. It is therefore hard to use on its own in hydroponics due to its tendency to cause waterlogging. However, when used in combination with rice husks, a medium with exceedingly tunable physical properties and very benign chemical properties appears.

River sand is chemically inert and provides a perfect compliment to rice hulls poor water retention properties

To prepare this media, mix 50% rice hulls by volume with 50% river sand. Rice hulls can be purchased for a very low cost, a 20 USD bag will be enough to prepare 400L of the medium. River sand is even cheaper and can be bought at around 50 USD per ton retail but can be bought wholesale at much lower prices. The density of river sand is around 1587 kg/m3, meaning that it will take around 317 kg to get 200L of sand. This means that the cost per 400L of final medium will be around 16 USD, taking the total cost of 400L of medium to 46 USD. This can be more cost effective than either peat moss, perlite, rockwool, or coco coir. Especially if you take into account that the media can be reused across several crop cycles.

Treating the medium before use

This medium needs to be treated before use, as rice hulls can contain some amount of rice that can be detrimental to seedlings. To treat it, water it with tap or RO water 3 days before use. This will ferment any of the remaining rice and the increase in temperature caused by this process will help get rid of insects and any pathogens present within the mix. Note that rice hulls are often parboiled, which means they have already been heated in boiling water, which will reduce the issue of pests.

Once this treatment is complete, you are ready to use the medium. You can also adjust the percentage of rice hulls and river sand in order to fit the particular dry back conditions you desire. More river sand will make the medium dry back slower, while more rice hulls will make the media dry back faster. This is similar to what happens when you mix perlite and coco or peat moss, with the advantage that river sand and rice hulls are much more chemically inert than these commonly used media types.

Conclusion

While not common in the US, mixes of rice hulls and river sand have been successfully used in hydroponic settings during the past 50 years in a wide variety of countries, especially South American ones. I have personally used them in both small and commercial-scale projects to grow from leafy greens to large flowering plants, with amazing results. This medium is chemically inert, very easy to tune, and has a low price point.

Had you heard of a mix of rice hulls and river sand as medium? Would this be cheaper than your current media choice? Let us know in the comments below!

How to make an organic hydroponic nutrient solution

Hydroponic nutrients are usually made with synthetic chemicals that come from industrial processes. While these chemicals are usually of a higher purity than those mined or obtained from animal or vegetable resources, it also means that these products contain no microbes or bio-stimulants and their origin implies they cannot be used in organically certified growing operations. Growers who want a more organic approach might still want to use hydroponic solutions, but traditional hydroponic fertilizers cannot be used due to the fact that they lack many of the traits desired in an organic fertilizer. In this post, I will show you how you can create a complete hydroponic solution from scratch using only OMRI-approved raw materials.

This seal is given to products that have been approved by the OMRI organization, which certifies which products can be used in organic culture

OMRI nutrient sources

A complete hydroponic solution should provide all substances that are necessary for plant growth. This means we need to provide nitrogen, phosphorus, potassium, magnesium, calcium, sulfur, iron, zinc, boron, copper, molybdenum, and manganese. Furthermore, we need to ensure that all of these nutrients are provided in forms that are available for the plants. This means we need to find sources that contain all the elements we need and then create a process that makes all of these nutrients adequately bioavailable. The following are the nutrient sources that we will be using, all of them are OMRI listed:

Please note the amazon links below are referral links. This means that I get a small commission when you choose to buy the products through these links, at no extra cost to you.

- Bark compost
- Solubor
- Copper Sulfate
- Corn Steep Liquor
- Ferti-Nitro Plus
- Iron Sulfate
- Magnesium Sulfate
- Manganese Sulfate
- Potassium Sulfate
- Seabird Guano
- Zinc Sulfate

Mixing the solution

This solution cannot be created in a concentrated form. This means we will be preparing a solution that will be fed directly to plants. However, since many of the inputs contain a lot of insoluble materials – due to their origin – there will need to be a filtration process in the end. This filtration step is necessary if you want to avoid problems dealing with the clogging of irrigation lines, in case you want to feed this into a regular irrigation system. If you want to hand water directly, then you can avoid this filtration step.

Since the solution is not concentrated, the amounts to be weighed can be small for some of the materials. For this reason, I advise you to prepare at least 100 gallons of solution, so that you don't require to weigh very small amounts of material. This will help keep the errors due to measurements low. To make this preparation you will need the following materials:

- A tank that can hold 100 gallons
- A flow meter to measure water flow
- A scale that can weight +/-0.01g max 500g
- An air pump rated for at least 100 gallons of water
- Air stones to diffuse air

To prepare the solution (100 gallons), follow these steps:

1. Add 50 gallons of water using the flow meter. Ideally use RO water, but you can use tap water as well if that is not possible.
2. Weigh and add all the ingredients per the table below.
3. Add another 50 gallons of water using the flow meter.
4. Place the air pump inside the solution and switch it on.
5. Maintain constant aeration for at least 15 days. Do not use it before this time has passed.
6. After 15 days have passed, filter the solution to use in irrigation lines or use directly to hand water. Keep air flowing through the solution even after the 15 days have passed.
7. The solution might also become basic during this process, if necessary, you can bring the pH of the solution down with citric acid before watering plants.

Bark compost	190
Solubor	0.65
Copper sulfate	0.15

Corn Steep Liquor	330
Ferti-Nitro Plus	220
Iron Sulfate	4
Magnesium sulfate	190
Manganese Sulfate	1
Potassium Sulfate	136
Seabird Guano	265
Zinc Sulfate	0.10

Table of ingredients to weigh. Masses are in grams.

The reason for the long wait

Plants ideally require nitrate in order to grow, the above inputs do not contain nitrate in appreciable amounts but mainly organic nitrogen sources. In this and this previous posts, you can learn more about organic nitrogen and why it is not ideal to use this in an unprocessed manner in a hydroponic crop. When you irrigate with organic nitrogen, most of the nitrogen will go unused and significant time will need to pass in the root zone for it to become available. The organic nitrogen decomposition process can also destabilize the pH of the root zone, making it harder for plants to properly absorb nutrients. By carrying out this process outside of the root zone, we make it easier on the plants, as we feed a pre-digested solution that is rich in available nutrients and microbes. The Seabird Guano and Bark compost, both provide the microbe inoculations necessary for the nitrogen decomposition process to take place. Oxygen, which we continuously pump into the solution, is also key to this process. The CSL and the Ferti-Nitro Plus will provide the organic nitrogen sources that will be decomposed.

This solution also contains a significant amount of amino acids. Although most of these amino acids will be converted into more readily absorbable nitrate through the digestion process, a small amount will be left undigested, which will lock onto the heavy metal ions. This will help prevent precipitation issues and provide the plant with organically derived chelates.

Also note that no specific molybdenum input is included. This is because it is present as an impurity in the corn steep liquor at a high enough concentration, so its explicit addition is not required.

Conclusion

The above solution should fully replace a traditional hydroponic solution, using only OMRI-approved materials. The final concentrations of nutrients should be spot on for the healthy development of most small and large plants. The solution will also contain a lot of microbes and bio-stimulants, which will also help plant growth. Of course, the final character of the solution will depend on the temperature of the digestion, the amount of aeration present, and the nature of the inputs used (as OMRI inputs have a significant amount of variability due to their sourcing). It might take a few tries to adjust this process to your particular conditions. Note that the above solution is intended to be used with soilless media that has not been amended, as it should provide all nutrients required for plant growth.

Did you prepare the above solution? Leave a comment telling us about your experience!

How to get more phosphorus in organic hydroponics

It is difficult to supply plants with readily available phosphorus because of the insolubility of many phosphorus compounds (2). Whenever orthophosphoric acid species are present in a solution, all the heavy metals, calcium, and magnesium form progressively insoluble phosphate salts as the pH increases (3). At high pH, all of the phosphate is expected to be precipitated as long as there are excess cations to form these insoluble salts. In this post, we are going to talk about how this problem exists mainly in organic hydroponics and how we can solve it by efficiently using organic sources of phosphorus.

Seabird guano, one of the few organic, high P, soluble sources for organic hydroponics

Phophorus in traditional hydroponics

In hydroponic systems that are not organic, soluble phosphorus salts are used to provide the phosphorus necessary for plant growth. These salts are all synthetic and are therefore not allowed for use in organic crops. They are mainly mono potassium phosphate (MKP) and mono ammonium phosphate (MAP). At the concentrations generally used in hydroponics – 25-100 ppm of P – at a pH of 5.8-6.2 and in the presence of chelated heavy metals, the phosphorus all remains soluble and there are rarely problems with phosphorus availability that are directly related to the P concentration in solution. However, when trying to move to an organic hydroponic setup where we want to avoid the use of all these synthetic salts, we run into big problems with P availability.

Organic soluble phosphorus fertilizers

The first problem we find is that there are no organic sources that are equivalent to MAP or MKP. However, there are thankfully some highly soluble organic sources that contain significant amounts of P. Some guano sources are particularly high in P, especially Seabird Guano (0-11-0), while some vegetable sources like corn steep liquor (CSL) (7-8-6) can also have high phosphorus (1, 9).

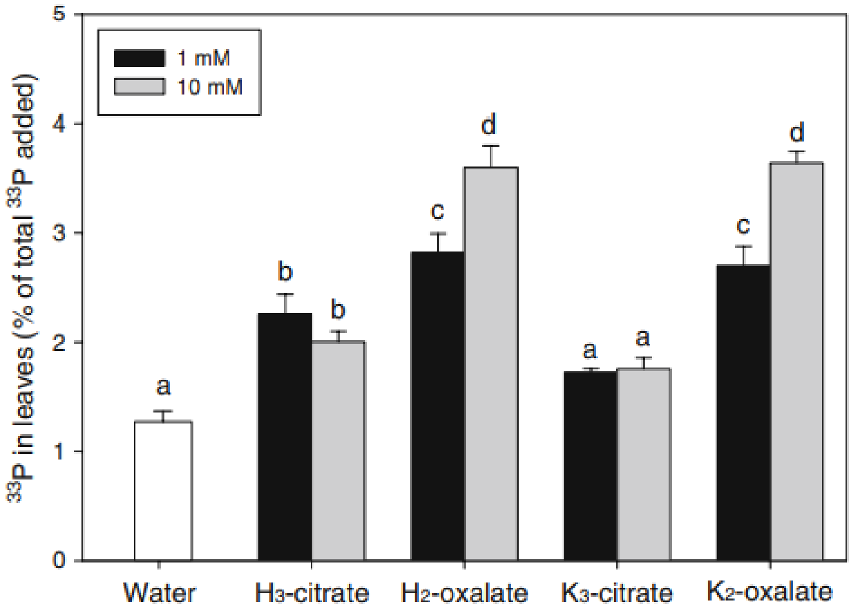
However, these sources do not only contribute phosphorus but will also contribute a variety of different substances that need to be taken into account when considering them for use. In the case of CSL, very high lactate and organic nitrogen levels imply that you will need to prepare an appropriate compost tea to use this in a nutrient solution. I wrote a blog post about a paper that describes how to make such a preparation.

In the case of seabird guano, a lot of calcium is also provided (20%) so we also need to take this into account in our formulations. *Using 3g/gal of seabird guano will provide you with a solution that contains 38ppm of P and 158ppm of Ca*, although not in exactly readily available form – as MKP would provide – it will become available much easier than insoluble phosphate amendments. Seabird guano applications should be enough to completely cover both the P and Ca requirements of most flowering plants. The seabird guano also includes a lot of microbial activity, which will reduce the oxygenation of the media when it is applied, reason why you need to be careful with the aeration properties of your media (as I mentioned in this post).

These organic sources of P might also contain significant amounts of heavy metals. Seabird guano can be notable for having significant levels of cadmium (4, 5) so make sure you have a heavy metal test of the soluble P source you intend to use to ensure you're not adding significant amounts of heavy metals to your crops.

Insoluble organic phosphorus amendments

Besides these soluble organic phosphorus sources, we also have the possibility to use mineral amendments that can be directly incorporated into the media from the start. These sources offer us some additional advantages relative to the pH and nutrient stability through time, which are not offered by using the soluble solutions. The most common amendments available in this area are rock phosphates and bone meal. Not all rock phosphates and bone meal sources are created the same though, rock phosphates mined across the world can differ in their carbonate content, which can greatly affect their solubility. *These amendments are generally used at around 60-120mL per gallon of soil.*



P uptake for different concentrations of citrate or oxalate.

Plants, however, will respond to low P in their root zone by releasing organic anions that can chelate metals and slowly dissolve these phosphates (6). Tests by adding organic acids directly do show that not all acids are the same and some are much more effective than others. In this article (7), the authors showed that oxalic acid was more effective than citric acid in making P available from a rock phosphate source. Malic acid, a very important organic acid for plants (8), can also be used for this purpose and is preferable to oxalic acid. This is because oxalic acid is not only toxic to humans but can also strongly precipitate metals like iron, which are also needed by plants.

From the literature, we can conclude that adding these acids ourselves in concentrations of around 1mM, can be a good way to help solubilize P contained in these rock phosphate amendments. Watering with a solution of citric or malic acid at 150mg/L (567mg/gal) can help free these rock phosphate amendments and contribute to plant absorption of both the phosphorus and the calcium that is bound with it. Alternatively, we can also use fulvic acid at 40mg/L to achieve a similar effect (10).

Conclusion

While there are no easy replacements for phosphorus in organic hydroponics, there are some satisfactory solutions. Soluble phosphorous sources like CSL and seabird guano can be used to provide large amounts of soluble P when required, while solid amendments like rock phosphate and bone meal can provide a sustained release of these nutrients with time, also increasing the pH stability of the media. While using only soluble sources can be the easiest initial transition from a purely hydroponic crop, it will also be harder to manage due to the effects on media pH that such applications might have. A combination of both approaches – soluble applications and amendments – can often be the most successful when implementing an organic hydroponic approach.

Why NFT is the best hydroponic system beginners should avoid

Nutrient Film Technique (NFT) is a hydroponic growing system that uses flat channels with nutrient solution flow – in the form of a thin film at the bottom of the channels – in order to grow plants. An NFT system will maintain maximum oxygen exposure to plant roots and a consistent nutrient supply, providing ideal conditions for plants. However, while NFT systems are extremely popular in large commercial operations, small scale growers and hobbyists rarely use them with the same success. Why is it that professionals like NFT systems so much, but yields decrease when small scale growers try it?

A commercial hydroponic NFT system

The fragility of NFT

The NFT setup provides an ideal set of conditions that is hard to maintain without significant effort. These systems demand control over a large variety of variables. This includes the flow of nutrient solution, the temperature of the air inside the channels, the chemistry of the solution and the sterilization of the nutrient solution. These are also all critical failure points for an NFT system. It is common for NFT setups to fail because of power failures, roots clogging channels, diseases spreading like wildfire, solutions becoming too hot or too cold, etc. The more things you have to control, the easier it is to fail to control one of those properly.

Commercial growers will generally have a lot of people and resources devoted to the monitoring of all these conditions and adequate standard operation procedures will generally be in place to address all these potential points of failure. Large growers often start from turn-key solutions with already well established expectations for issues and their solutions, something that small growers generally lack. By design, NFT requires a lot of planning for contingencies, small growers and amateur growers don’t do this as well as large companies.

Decision skills

One of the most critical aspects of NFT systems is that the time between decisions and consequences is quite fast. If roots grow to the point where a channel is being significantly obstructed and a grower does not realize there is a problem and acts fast, then the crop will be very negatively affected. In one crop I consulted with, a 24 hour delay in noticing the start of a fungal disease, generate a massive loss of plants in the crop. The solution was not being adequately sterilized in recirculation, which was a huge oversight and failure point for the crop. Thankfully, this grower was producing lettuce – which is easier to recover from as the crop cycle is short – but this can be devastating for a flowering plant grower, where crop cycles are much longer.

NFT rapidly spreads disease across plants. Taken from this paper.

This ability to find problems fast and solve them quickly requires a lot of focus and attention. Small scale growers are generally distracted by many other aspects of the crop, from financials and distribution in small scale commercial operations, to just regular life and normal jobs in family setups. For this reason, these problems generally go unattended in these crops, which leads to problems from lower yields, to total crop failure.

A lot of small problems

Perhaps most insidious, is the fact that many problems in an NFT setup can go completely unnoticed during a crop cycle, eating at yields before they are apparent. While commercial growers will have expectations set by consultants and system builders, the small scale grower will have no idea that certain things need to be looked at within a crop cycle.

For example, channel length can be critical in NFT setups, as plants that receive the feed at the start of a channel can deplete a solution from key nutrients by the time it reaches the end of the channel. This issue can go on through an entire crop cycle without the grower ever noticing anything except reduced yields. This might lead a grower to think that the NFT system is somehow leading to lower yields, while it is their particular implementation of NFT and not NFT as a whole that leads to worse results.

Small scale growers tend to have less time and resources, so they will tend to ignore problems that are not very obvious. The sum of all these problems will tend to cause a substantial erosion of yields. In my experience, small scale growers will, on average, achieve much better results with systems that are more forgiving than with a potentially more productive but substantially more complicated setup.

Plants in NFT setups can grow huge roots that can easily clog drains or prevent proper flow across the channel. Trimming roots when this happens is fundamental for system survival.

Why large scale growers use it

You might be thinking, why do commercial growers bother with NFT then? If it is so complex and prone to failure, then why in the world would you choose a system like this? The answer, is that NFT can be a very high yielding, low cost and reproducible alternative at a medium to large commercial scale. It avoids one huge cost – which is the purchase and labor costs associated with media – and focuses all energy into the production of plants. An NFT crop is also much more efficient from a water and fertilizer usage perspective (1). This means that, for a large scale commercial grower, dealing with the complexities of an NFT system is preferable to dealing with the additional costs, labor and inefficiencies of a media based system. Having to handle way less nutrient solution volume, no media and getting basically the same or superior yield, is a no-brainer for commercial growers.

A medium to large scale greenhouse will have people dedicated to growing, whose main job will be to monitor the crop and ensure that it is performing as specified by the manufacturer. With more than 70 years of experience in the setup of hydroponic crops, many companies offer turn-key solutions that have clearly set management procedures and outcomes for several different plant species. This is especially true for leafy greens, cucumbers, tomatoes, peppers and strawberries, all very commonly produced using NFT systems.

What should the little guy do then

For commercial growers, the benefits of NFT often overcome its disadvantages. However, for the small grower looking for more reliable production of crops, even if it means at lower fertilizer and water use efficiency, it often doesn’t make sense to go with NFT setups. For small growers who want to avoid media, deep water culture (DWC) offers an easier and more reliable alternative. For those wanting to grow with lower starting costs, open media-based systems give the best success rates, even if this implies significantly lower efficiency from almost all points of view.

If this is your first try at hydroponics or if you want to go with a small scale commercial setup, my advice would be to go with a system that is more forgiving and that you have the time and skill level to properly manage. Once you master these systems, you can try NFT, but bear in mind that your initial results might be worse than what you were doing before, just because the level of skill and knowledge required to successfully manage an NFT setup is substantially higher.

Organic nitrogen in hydroponics, the proven way

Nitrogen is a critical nutrient for plants. In hydroponics, we can choose to provide it in three ways, as nitrate, as ammonium or as organic nitrogen. This last choice is the most complex one. It contains all possible nitrogen-containing organic molecules produced by organisms, such as proteins and nucleic acids. Since nitrate and ammonium are simple molecules, we know how plants react to them, but given that organic nitrogen can be more complicated, its interactions and effects on plants can be substantially harder to understand. In this post, we will take an evidence-based look at organic nitrogen, how it interacts in a hydroponic crop and how there is a proven way to use organic nitrogen to obtain great results in our hydroponic setups.

An organic nitrogen source, product of corn fermentation, rich in protein and humic acids

Nitrogen uptake by plants

The main issue with organic nitrogen is its complexity. Plants will mainly uptake nitrogen as nitrate (NO_3^-) and will also readily uptake nitrogen as ammonium (NH_4^+) to supplement some of their nitrogen intake. However, organic nitrogen is made up of larger, more complex molecules, reason why its uptake is more complicated. Various studies have looked into whether plants can actually uptake organic nitrogen directly at all

(1, 2). They have found that while some uptake is possible, it is unlikely to be the main contributor to a plant's nitrogen uptake. While plants might be able to uptake this organic nitrogen to some extent, especially if it is comprised of smaller molecules (3, 6), it is unlikely that this nitrogen will be able to replace the main absorption pathway for nitrogen in plants, which is inorganic nitrate.

Effects of organic nitrogen in hydroponics

Many researchers have tried to figure out what the effect of organic nitrogen is in hydroponics. This study (4), looked at the effect of various organic nitrogen sources in the cultivation of lettuce. The study tried to measure how these fertilizers compared against a complete Hoagland solution. The results show that the organic nitrogen sources were unable to successfully compete with the standard mineral nutrition. The best result was obtained with blood meal, with less than half of the yield obtained from the Hoagland solution. It is clear that this study is not fair, as using organic nitrogen sources as the sole source of nutrition means more deficiencies than simply nitrogen might be present, but it does highlight some of the challenges of using organic nitrogen in hydroponics.

Another study (5), performed a more direct comparison of various different nitrogen sources, changing only the nitrogen source between nitrate, ammonium, and organic nitrogen in the cultivation of tomatoes. Organic nitrogen performed the worst across most measurements in the study. This showed that organic nitrogen is, by itself, not a suitable form of nitrogen for plant absorption and is unable to replace the nutrition provided by a synthetic inorganic nitrate source. This is especially the case when the organic nitrogen comes from more complex sources.

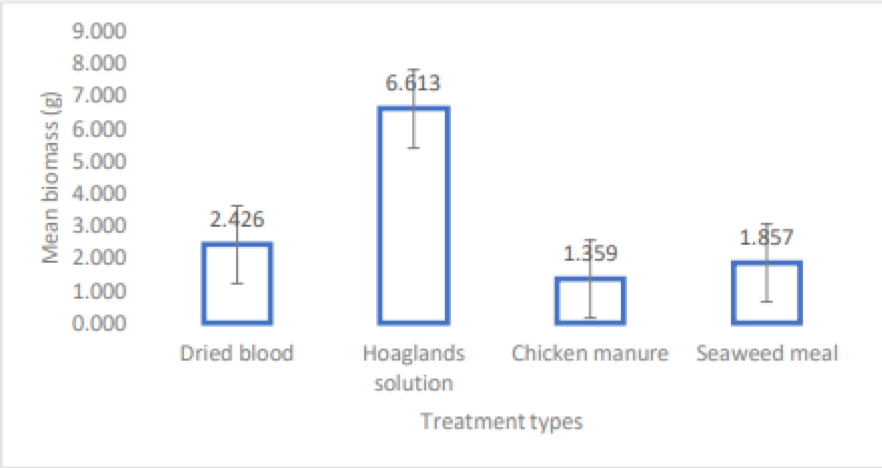


Figure 10: Compares the mean values for dried lettuce biomass of the four different treatment types.

Taken from this thesis.

How to solve these issues

As we've seen, the main problem with organic nitrogen is that plants cannot uptake it efficiently. However, the nitrogen cycle provides us with mechanisms to convert organic nitrogen into mineral nitrate which plants can readily metabolize. The best way to achieve this is to prepare compost teas using the organic nitrogen source to create a nutrient solution that is better suited for plants. The use of nitrifying organisms provides the best path to do this. These organisms are present in a variety of potting soils and composts, but can also be bought and used directly.

This study (7) showed how using goat manure coupled with nitrifying bacteria was a viable path to generate a nutrient solution suitable for plant growth. Another study (8), also using manure, confirms that viable nutrient solutions can be created and used to grow crops successfully when compared to hydroponic controls. Manure, as an animal waste product, contains a lot of the macro and micronutrients necessary for plant growth, providing an ideal feedstock for the creation of a full replacement for a nutrient solution.

Another interesting study (9) uses vegetable sources in order to study the creation of such solutions. I recently used this study to create a detailed post about how to create a nitrate-rich compost tea for use in hydroponics starting from corn steep liquor and bark compost as inputs.

In conclusion

Organic nitrogen sources, by themselves, are not suitable as the main source of nitrogen for plant growth. This is especially true of very complex nitrogen sources, such as those contained in blood meal, corn steep liquor and fish emulsions. However, we can take advantage of nitrifying bacteria and use these inputs to create nitrate-rich solutions that can be used to effectively grow plants. *This is a proven solution that has been tried and tested in multiple studies and in nature for hundreds of thousands of years*. Instead of attempting to use organic nitrogen sources either directly in the hydroponic solution or as media amendments, create compost teas with them that contain readily available mineral nitrate instead.

Do you use organic nitrogen in hydroponics? What is your experience?

Aquaponics vs hydroponics, which is best and why?

In hydroponic culture, plants are grown with the help of a nutrient solution that contains all the substances required for plant growth. In these systems, the nutrient solution is prepared using externally sourced chemicals, which can be of a synthetic or natural origin. On the other hand, in aquaponics, a plant growing system is coupled with an aquaculture system – a system that raises fish – so that the plants feed on the waste coming from the fish. In theory, aquaponics offers the benefits of a simplified, closed system with an additional upside – the ability to produce fish – while a hydroponic system requires a lot of additional and more complicated inputs. Through this post, we will use the current peer-reviewed literature to take a deep look into aquaponics vs hydroponics, what are the advantages and disadvantages and why one might be better than the other. A lot of the information below has been taken from this 2019 review on aquaponics (9).

Basic process diagram of an aquaponic setup (from here)

Complexity

An aquaponic system might seem simpler than a hydroponic system. After all, it is all about feeding fish regular fish food and then feeding the waste products to plants. However, it is actually not that simple, since there are substantial differences between the waste products of fish and the nutritional needs of plants. One of the most critical ones is nitrogen.

This element is excreted by fish in its ammoniacal form but plants require nitrogen in its nitrate form. This means that you need to have a biofilter system containing bacteria that can turn one into the other. Furthermore, the chemical conditions ideal for nitrification are basic, while plants prefer solutions that are slightly acidic. This mismatch in the optimal conditions of one system compared to the other makes the management of an aquaponic system substantially more complicated than the management of a traditional hydroponic system (1).

Furthermore, plant macronutrients like Potassium and Calcium and micronutrients like Iron are often present at low levels in aquaponic solutions. Plants that have higher demands for these elements, such as large flowering plants or some herbs, might have important deficiencies and issues when grown in an aquaponic system (2, 3). This means that supplementation is often required in order to achieve success with these crops. Achieving ideal supplementation rates often requires chemical analysis in order to properly gauge the amounts of these elements that are required.

Additionally, aquaponic systems require additional area for fish and a lot of additional labor to manage the fish, the biofilters, and other sections of the facility that would not exist under a purely hydroponic paradigm. This article (16), better describes some of the economic and practical tradeoffs in terms of complexity when going from a hydroponic to an aquaponic facility.

Yield and quality

Given the above, it could be easy to think that yields and quality of products coming from aquaponics would be worse. However, the evidence points to the contrary. Multiple studies looking at aquaponics vs hydroponics quality and yields have shown that aquaponics products can be equivalent or often superior to those produced in hydroponic environments (4, 5, 6, 7, 8). A variety of biological and chemical factors present in the aquaponic solution could offer bio-stimulating effects that are not found in traditional hydroponic solutions. For a detailed meta-analysis gathering data from a lot of different articles on aquaponics vs hydroponics see here (14).

The best results are often found with decoupled aquaponic systems. In these systems, the aquaponic system is treated as separate aquaculture and hydroponic systems. The nutrient solution is stored in a tank that is used by the hydroponic facility as its main feedstock to make nutrient solution. Its chemistry is then adjusted before it is fed to the hydroponic system.

An aquaponic setup growing leafy greens

Growing Systems

Traditionally, Nutrient Film Technique (NFT) systems have been preferred in commercial hydroponic culture due to their high yield and effectiveness. However, aquaponic systems do better with setups that can handle large levels of particulates, due to their presence in the aquaponic nutrient solution. For this reason, deep water culture (DWC) is the preferred method for growing in commercial hydroponic systems. This is also because dark leafy vegetables are the most commonly grown products in aquaponic setups and DWC setups are particularly well suited to grow this type of plants.

Sustainability

Aquaponic systems are, on average, more sustainable than hydroponic systems in terms of fertilizer usage. When comparing Nitrogen and Phosphorus usage between a hydroponic and an aquaponic crop, it seems to be clear that aquaponic crops are much more efficient (12). An aquaponic crop can offer the same quality and yield with drastically lower fertilizer use and carbon dioxide emissions due to these facts (13).

The aquaponic closed system diagram, taken from here

The economics

Due to the poor nutritional characteristics of the aquaponic solutions for flowering plants, most aquaponic growers have resorted to the growing of leafy greens. A 2017 study (10) showed that profits from growing basil were more than double of those attained by growing Okra, due to the fact that basil could be grown with little additional supplementation while Okra required significant modification of the aquaponic solution to fit the plants' needs.

Due to the fact that large flowering plants require large amounts of mineral supplementation in order to be grown successfully in aquaponics, they are seldom grown in aquaponics setups. Since leafy greens eliminate the need for such supplementation, can be grown faster, and suffer from substantially less pest pressure, it is a no-brainer in most cases to grow leafy greens instead of a crop like tomatoes or peppers. However, high-value crops like cannabis might be attractive for aquaponics setups (10, 11).

Aquaponics often require economies of scale to become viable. The smallest scale aquaponic setups, like those proposed by FAO models, can offer food production capabilities to small groups of people, but suffer from a lack of economic viability when the cost of labor is taken into account (12). It is, therefore, the case that, to be as profitable as hydroponics, aquaponic facilities need to be implemented at a relatively large scale from the start, which limits their viability when compared with hydroponic setups that can offer profitability at lower scales. As a matter of fact, this 2015 study (15) showed that most aquaponic farms were implemented at relatively small scales and had therefore low profitability values.

Nonetheless, aquaponics does offer a much more sustainable way to produce food relative to conventional hydroponic facilities and does offer economic advantages, especially in regions where low water and fertilizer usage are a priority (14).

Which one is best then?

It depends on what your priorities are. If you want to build a setup with few uncertainties that can deliver the most profit at the smallest scale, then hydroponics is the way to go. Aquaponic setups have additional complexities, uncertainties, needs of scale, and limitations that hydroponic crops do not have. Building a hydroponic commercial setup is a tried-and-tested process. Hydroponics offers predictable yields and quality for a wide variety of plant products. There is also a wide industry of people who can help you achieve this, often with turn-key solutions for particular plant species and climates.

On the other hand, if you want to build a setup that is highly sustainable, has as little impact as possible on the environment, has very low fertilizer and water use and can deliver the same or better quality as a hydroponic setup, then aquaponics is the road for you. Aquaponics has significantly lower impact – as it reduces the impact of both plant growing and fish raising – and can deliver adequate economic returns if the correct fish and plant species are chosen.

In the end, it is a matter of choosing which things are most important for you and most adequate for the circumstances you will be growing in. Sometimes, limited fertilizer and water availability, coupled with higher demand for fish, might actually make an aquaponic setup the optimal economic choice versus a traditional hydroponic setup. However, most of the time a purely economic analysis would give the edge to a hydroponic facility.

If you are considering building an aquaponic system, a decoupled system that produces Tilapia and a deep water culture system producing dark leafy greens seems to be the most popular choice among commercial facilities.

Which do you think is better, aquaponics or hydroponics?

The ultimate EC to ppm chart and calculator

Electrical conductivity (EC) meters in hydroponics will generally give you different types of readings. All of these readings are conversions of the same measurement – the electrical conductivity of the solution – but growers will often only record one of them. The tools presented in this page will help you convert your old readings from one of these values to the other, so that you can compare with reference sources or with readings from a new meter. In this page you can figure out the scale of your meter, convert from ppm to EC and from EC to ppm.

The TDS reading of different meters will be done on different scales, so it is important to know the scale of your meter in order to perform these conversions. These scales are just different reference standards depending on whether your meter is comparing the conductivity of your solution to that of an NaCl, KCl or tap water standard. To learn more about how TDS scales work I would suggest you watch my youtube video on the subject. **To compare the readings from different meters, always compare the EC (mS/cm) reading, do not compare ppm readings unless you are sure they are in the same scale.**

My go-to EC meter recommendation is the [Apera EC60]

To figure out the scale of the meter, measure the EC (mS/cm) and TDS (ppm) of the exact same solution with your meter. After this, input the values in the first calculator below. You can then use this scale value to convert between EC and ppm using the other two calculators below. If you already know the scale of your meter you can use the other two calculators and skip the first step. The meter scale will usually be 500, 600 or 700.

Figure out the Scale of the Meter

TDS (ppm) reading:

EC (mS/cm) reading:

Calculate

Meter scale:

Convert ppm to EC

TDS (ppm) reading:

Meter scale:

Calculate

EC in mS/cm:

Convert EC to ppm

EC reading mS/cm:

Meter scale:

Calculate

TDS (ppm) reading:

Create a table for reference

Meter scale:

Generate Table

If you would like to learn more about EC readings in hydroponics I would suggest reading the following posts on my blog:

- Comparing the conductivity of two different solutions
- Improving on HydroBuddy's theoretical conductivity model, the LMCv2
- FAQ – Electrical Conductivity (EC) in Hydroponics