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:

- 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).

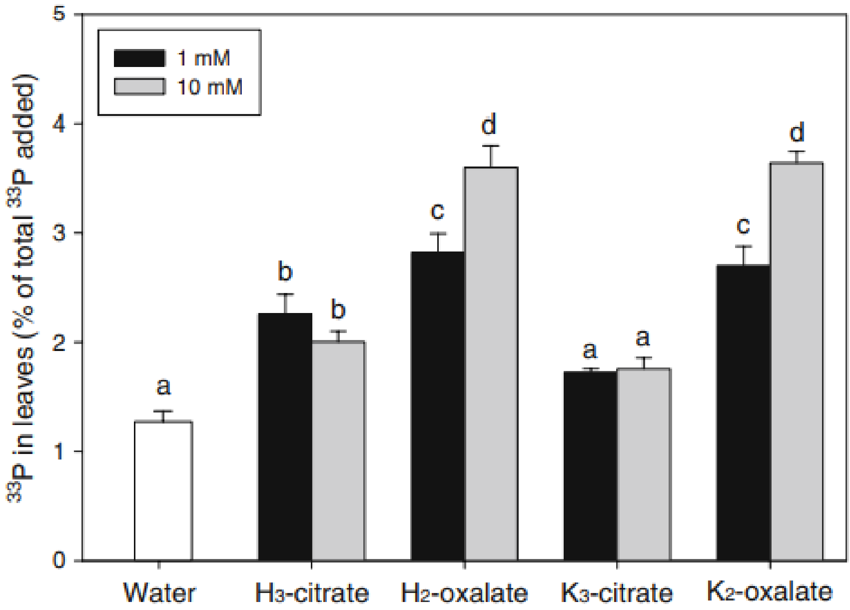
However, these sources do not only contribute phosphorus but will also contribute a variety of different substances that need to be taken into account when considering them for use. In the case of CSL, very high lactate and organic nitrogen levels imply that you will need to prepare an appropriate compost 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.

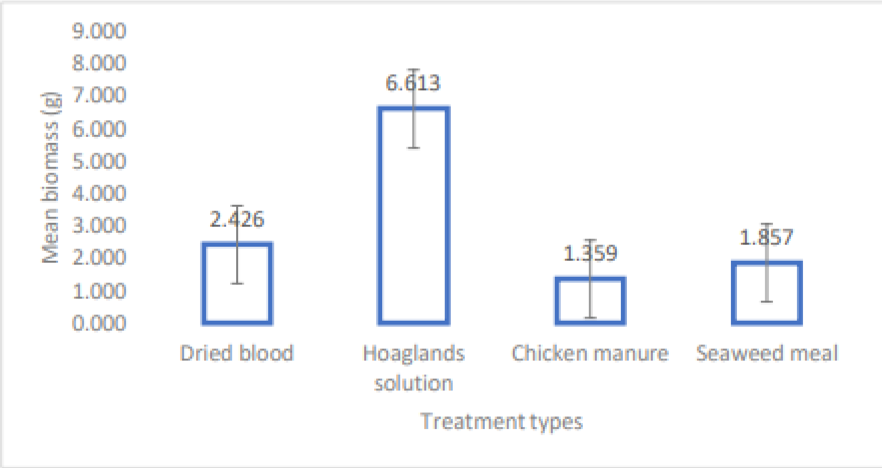


Figure 10: Compares the mean values for dried lettuce biomass of the four different treatment types.

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.

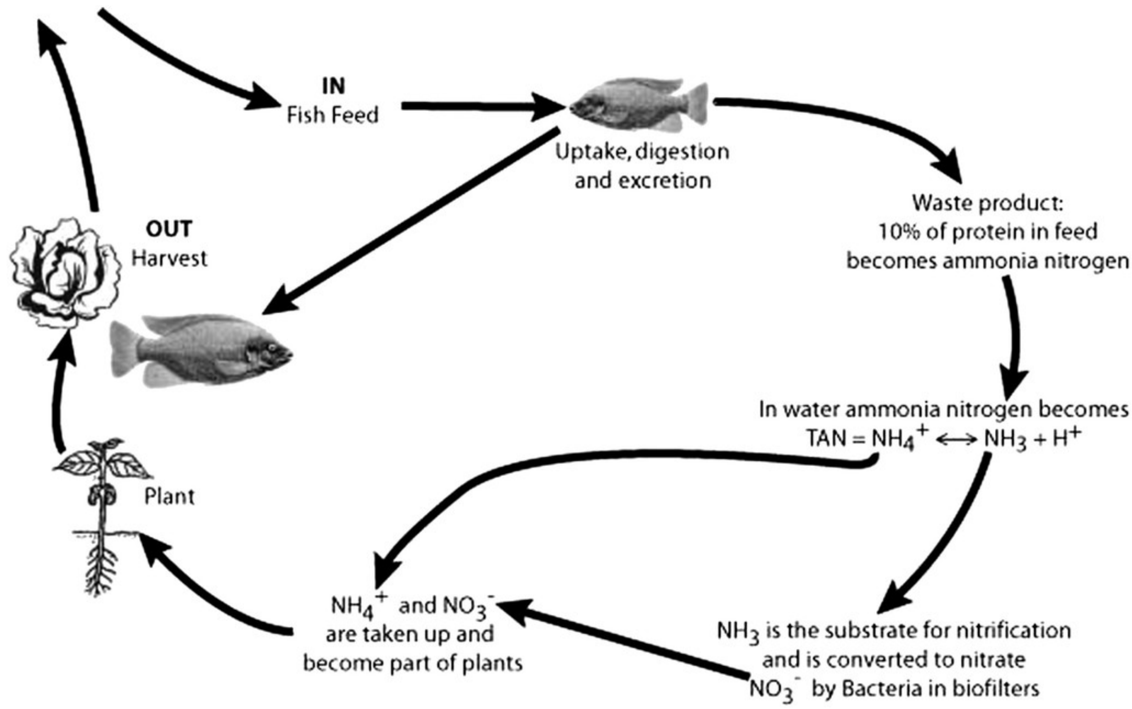
In conclusion

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.

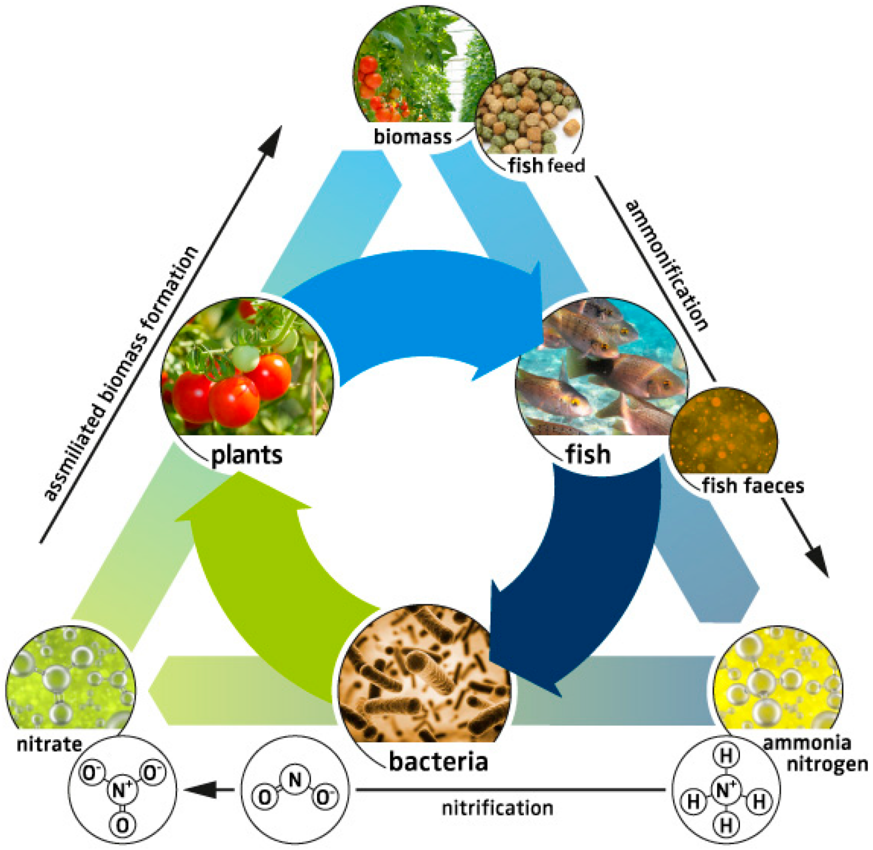
An aquaponic setup growing leafy greens

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?

A powerful organic fungicide for powdery mildew

Powdery mildew (PM) is a hard disease to fight. It affects plants of multiple different species and causes big crop losses around the world. Although the best treatment against it is prevention, there are still ways to combat the pathogen and reduce crop losses once plants are infected. There are a lot of products currently being marketed to try to fight these fungi but many of these products are systemic fungicides that cannot be easily used in eatable crops, especially when getting closer to harvest dates. In this post, I want to share with you a formulation for an all-organic and powerful fungicide, backed by peer-reviewed research, that you can use as a strong line of defense against PM. Also checkout my previous post detailing the recipe for a natural fungicide based on a US patent to fight fungal disease.

A lot of research has been done to deal with PM. This disease is sadly not caused by a single species of fungus but is actually an array of different species of fungi that attack multiple different plants, showing similar symptoms. Thankfully, there are several organic treatments that have been found to be effective against many of the fungi that cause this problem.

Jojoba beans and oil

Vegetable oils have been some of the more effective solutions found. Sunflower oil was found to be quite effective in the treatment of PM in tomato crops (1). Emulsions of vegetable oils with yolk have also been found to be effective fungicides to treat PM in cucumber (2). As a matter of fact, many cooking oils, including safflower, olive, corn, and soybean, show some control properties against PM, especially when they are properly emulsified and can spread evenly on leaves. Their main mode of action seems to be to inhibit the germination of spores.

More chemically active plant oils have also been found to work against powdery mildew. This review (3) highlights some of the research that was done until 2014 for the control of PM using this sort of chemicals. Essential oils such as Hyssop (4), citronella, lemongrass, eucalyptus, cinnamon, tea tree (5), and many others have been tried, but although active in PM control, few have been able to give broad efficacy across multiple plant species. However, Jojoba oil has been one of the few oils with consistent results across multiple plant species (6, 7, 8). Japanese knotweed oil has also proved effective (9, 10, 11), although it is considerably more expensive.

Comparison of multiple different treatments in the inhibition of powdery mildew spore germination. Taken from this article.

It is also key to realize that the effectiveness of the above oil treatments hinged on the proper emulsification of these oils with water. This means that an adequate formulation should contain a surfactant to help disperse the oils into the water. The papers cited above use either completely synthetic emulsifiers – such as Tween 20 – to natural emulsifiers such as milk or yolk. However, one of the most popularly used and effective organic emulsifiers, yucca extract, could help us better emulsify these oils for their use as foliar sprays.

To prepare the organic fungicide for the prevention and treatment of PM, use 1g/gal of yucca extract, 45mL/gal of Jojoba oil, and 25mL/gal of sunflower oil. Add the yucca extract first and mix till it's all dissolved, then add the oils and mix well before application. Ensure the oils are completely emulsified before performing an application. You can apply this as a foliar spray once per week.

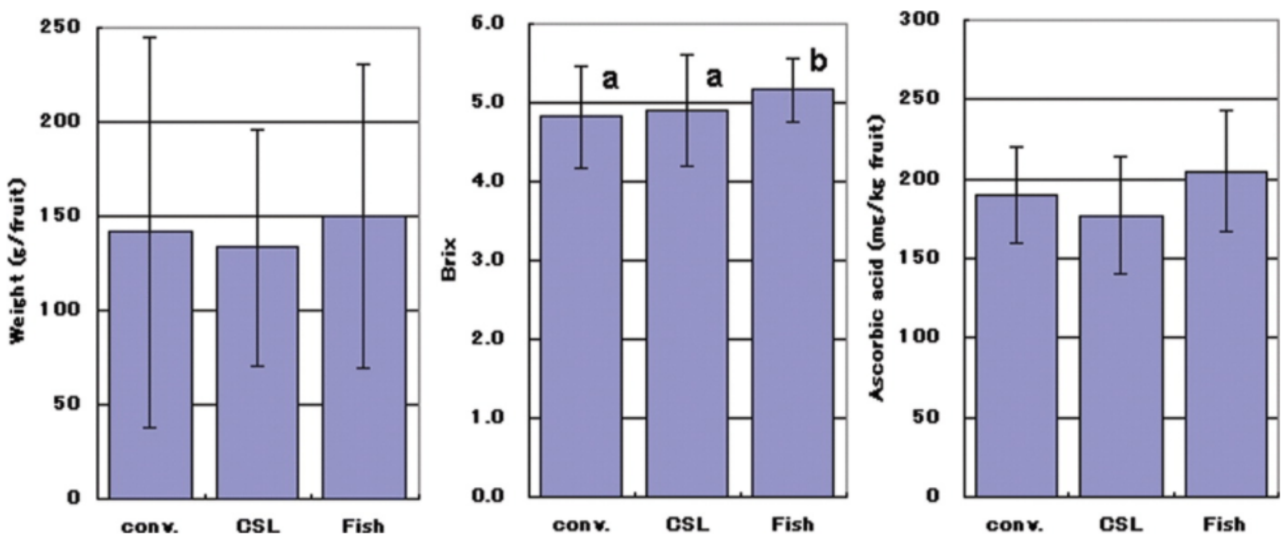
Making a nitrate rich compost tea for organic hydroponics

Organic hydroponic solutions – meaning solutions derived from organic inputs – contain a lot of nitrogen derived from organic sources that are mainly in either ammonium or protein form. These forms of nitrogen can be useful when decomposed by microbes but can be hard for your plants to use before this decomposition process takes place. Nitrate, the form of nitrogen plants crave the most, is not easy to add directly in an organic setting, because most available nitrates are synthetic – therefore cannot be used – and mined sodium nitrate, the only one that can be used under OMRI guidelines, contains a large amount of sodium, which is not beneficial for plants. However, we can create compost teas that contain a high enough level of nitrates, that will be eagerly taken up by our plants and contain little to no sodium, starting from no mined materials.

Results of using either conventional chemical fertilizers (a), compost tea made with CSL (b) or compost tea made with fish emulsion (c). Taken from here.

In order to do this, we will take advantage of a research paper that was published in 2010, on the creation of nitrate-containing fertilizers from organic sources. The process takes advantage of the presence of saprophytic bacteria – those that recycle dead organisms – in several different organic materials and puts them into contact with organic inputs that are high in protein or ammonium nitrogen. With time, this creates a nitrate-rich solution that contains virtually no left-over protein or ammonium. In the paper, they tried many different organic nitrogen sources, sources of bacteria, and processing times. The process I will describe hereafter is taken from an examination of these results and what they found worked best.

The first thing we require is an organic source of nitrogen. From the many that they tried, only fish emulsion and corn steep liquor (CSL) offered high enough conversion rates into nitrate. Between these two, I would recommend using CSL, since fish emulsion can be very smelly, which can be a very important factor when large amounts are being used. The second thing we require is a source of bacteria capable of carrying out the conversion. They tried several, all with good conversion rates, but their preferred source ended up being bark compost, due to its wide availability and reproducibility.



Growth and quality of tomato plants grown with conventional mineral fertilizers and either CSL or fish emulsion derived compost teas. Taken from here.

To create the starting solution, add CSL at 1g/L and bark compost at 0.5g/L. To prepare 5 gallons of the starting solution, you would add 19g of CSL and 9.5g of bark compost. You should then connect an aeration pump into this solution, to ensure ample oxygen is available for the conversion processes. The entire process will take around 12 days. After this time has passed, you can then use this final compost tea as a nutrient solution. If you want to know what the results of your process were, I would recommend you use a nitrate ISE from Horiba which you can use to measure the final nitrate concentration of your solution. You would expect to measure around 450-600 ppm of nitrate with this meter, which would be equivalent to 100-130 ppm of N as nitrate. Since different CSL sources will have different NKP values, you might need to adjust your CSL additions to come up with better numbers. However, the above numbers should generate nitrate levels in a reasonable range.

Overall, this paper shows that a solution derived in this manner can be used to successfully grow tomatoes when compared to normal chemical fertilizers. However, note that the media did contain some amendments, as the above solution is not able to provide significant amounts of Calcium or Magnesium. Although this compost tea can provide a lot of the nutrition required, it cannot replace a full hydroponic solution when fully inert media is used. By adjusting the amount of CSL used in the process, you should also be able to control the amount of N, P, and K present in the final solution. This should allow you to create a great compost tea that can be used for the successful growing of organic hydroponic crops.

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

Never fail with ebb and flow hydroponic systems

Ebb and flow or “flood and drain” systems, are some of the most popular systems built in hydroponics. These are low cost, can host a large number of plants, and can generate good results, reason why they are a preferred choice for both new and experienced hydroponic growers. However, there are a substantial number of issues that can come up in these systems, both due to the different ways they can be built and because of failures in their management. In this post, I am going to give you some tips on the construction and management of ebb and flow systems so that you can minimize the chances of failure when building your own hydroponic setup of this kind. For some basics of how an ebb and flow system is set up, I advise you to watch this video.

Ensure full drainage

A common mistake when building a flood and drain system is to have incomplete drainage of the nutrient solution. Make sure you have a setup that allows for complete drainage of the solution as soon as a certain level is reached, and always stop pumps as soon as the return of the solution starts. It is quite important to also ensure that as little solution as possible remains at the bottom of your flood and drain trays or buckets, as plants sitting in puddles of water can be a recipe for disease and a very good environment for pests to develop. A very simple system I built in 2010 had the problem of never being able to efficiently drain, which caused substantial issues with the plants as root oxygenation was never as good as it should have been.

Typical flood and drain table with plants in media on top of the table.

Fast cycle speed

Ideally, you would want the flood and drain cycle of an ebb and flow system to be as fast as possible. Also, the cycles should not take more than 15 minutes, from starting to flood the growing table to completely draining the system. For this, you need to have an adequately sized pump for the volume of your table that needs to be filled (total volume minus volume taken up by plants and media). If you want to use a smaller pump, you can always add some rocks to the table in order to take up volume and ensure you require to add less volume to fully flood the reservoir. Time your cycles and make sure these are as short as possible, adequately saturate the media and completely drain, as mentioned above.

The right media

A common reason why flood and drain systems are less productive is because of a suboptimal choice of media. Ebb and flow systems periodically flood the media with nutrient solution, completely saturating it with water, so media that retains too much moisture will require infrequent cycles and will be harder to time. Media like peat moss and coco are often inadequate for ebb and flow systems due to this fact, as over-saturation of the media will lead to periods of low oxygen availability for the plants. Media that drain fast generally do much better, choices such as rockwool or perlite can give much better results when compared with media that have much higher moisture retention. Since this is a recirculating setup, perlite and rockwool also have the advantage of being more chemically inert. I however do not like media that drain too fast, such as clay pellets, as these can require too frequent cycling.

Another typical ebb and flow table setup

Time irrigations with water content sensors

Your flood and drain system requires good timing of irrigation cycles in order to have optimal results. If you irrigate based on a timer, you will over irrigate your plants when they are small and will under irrigate them when they are big. Overwatering can be a big problem in these systems and it can be completely solved by both choosing the right media – as mentioned above – and using capacitive water content sensors for the timing of your irrigations. If you're interested in doing this, check out this post I wrote about how to create and calibrate your own simple setup for using a capacitive water content sensor using an Arduino. This will allow you to flood your table only when it is needed and not risk over watering just because of a timed event happening.

Oversize the reservoir

The nutrient reservoir contains all the nutrition that is used by the plants, this means the bigger this is relative to the number of plants you have, the lower the impact of the plants per irrigation event will be. Having a reservoir that has around 5-10 gallons per plant – if you're growing large flowering plants – or 1-3 gallon per plant, for leafy greens, will give you enough of a concentration buffer so that problems that develop do so slowly and are easier to fix. A large reservoir can fight the effects of plants more effectively and make everything easier to control.

Add inline UV sterilization

Disease propagation is one of the biggest problems of this type of system. Since recirculation continuously redistributes any fungal or bacterial spores among all the plants, it is important to ensure you have a defense against this problem. A UV filter can help you maintain your reservoir clean. You can run the solution through the inline UV filter on every irrigation event, ensuring that all the solution that reaches the plants will be as clean as possible. Make sure you use a

UV filter that is rated for the gallons per hour (GPH) requirements of your particular flood and drain system. Also read my post about [getting read of algae](), to learn more about what you can do to reduce the presence of algae in a system like this.

Typical UV in-line filter used to sterilize a nutrient solution in a hydroponic setup. These are sold in aquarium shops as well.

Run at constant nutrient EC, not reservoir volume

One of the easiest ways to manage a recirculating system, especially with an oversized reservoir, is to keep it at constant EC instead of constant volume. This means you will only top it off with water in order to bring the EC back to its starting value, but you will never add nutrients to the reservoir. This will cause your total volume to drop with time as you will be adding less volume each time to get back to the original EC. When the volume drops to the point where you have less than 50% of the original volume, completely replace your reservoir with new nutrients. This gives you a better idea of how “used up” your solution really is and how close to bad imbalances in the nutrient solution you might be. A large flowering plant will normally uptake 1-2L/day, meaning that with a reservoir sized at around 5 gallons per plant, it will take you around 2-3 weeks to replace the water.

Note that more efficient and complicated ways to manage a nutrient reservoir exist, but the above is a very safe way to do so without the possibility of toxic over accumulations of nutrients from attempts to run at constant volume by attempting to add nutrients at a reduced strength to compensate for plant uptake. Topping off with nutrients without regard for the changes in the nutrient solution chemistry can often lead to bad problems. The above approach is simple and gives good results without toxicity problems.

Change your pH according to the return pH values

Instead of watering at the normal 5.8-6.2 range, check the pH of the return on a drain cycle to figure out where you should feed. Since a flood and drain system is not a constantly recirculating system, the solution conditions do not necessarily match the root zone conditions and trying to keep the solution at 5.8-6.2 might actually lead to more basic or acidic conditions than desired in the root zone. Instead, check for the return pH to be 5.8-6.2, if it is not, then you need to adjust your reservoir so that it waters at a higher or lower pH (always staying in the 5-7 range) in order to compensate for how the root zone pH might be drifting. This can take some practice, but you can get significantly better results if you base your pH value on what the return pH of your solution is, rather than by attempting to set the ideal pH at the reservoir. You will often see that you will be feeding at a consistently lower pH 5.5-5.6, in order to accommodate nutrient absorption.

Finally

The above are some simple, yet I believe critical things to consider if you want to succeed with an ebb and flow system. The above should make it much easier to successfully run a setup of this kind and grow healthy and very productive plants. Let me know what you think in the comments below!