BROOKLYN GRANGE

Organic Hydroponics Research

Funded through the NRCS Conservation / Innovation Grant

Progress Report September 2022

This is an 8-month update for a two-year project researching methods for improving the sustainability of hydroponic operations. The primary focus is using aquaponic filtering technology such as biofiltration to improve the commercial viability of organically-sourced inputs. The purpose of this document is to share our findings thus far and seek outside perspectives.

BACKGROUND

Conventional hydroponic methods in the Global North rely on mined and heavily processed materials for substrates and fertilizers. Many growers are interested in using more sustainable inputs, but there are several well-established challenges. For example, organically sourced fertilizers tend to have unstable pH, inconsistent nutrient availability, and clogging in narrow irrigation lines. These same challenges are commonly overcome in aquaponics. This project focuses on trialing different fertilizers and growing media using aquaponics filtering techniques. We're using part of an existing commercial hydroponic space at Brooklyn Grange in Sunset Park – a soil based rooftop farm with a greenhouse in Brooklyn, New York. The goal is to find a combination that is more sustainable, but still commercially viable at a small farm scale.

A secondary goal is sharing our findings to fellow growers and curious consumers. A lot of industry knowledge about hydroponics is difficult to access because it's proprietary or complicated. Farming food hydroponically is a growing industry, which includes urban farms, but the bulk of the growth is greenhouse complexes in rural areas.[1] Given the potential and expanding scope of hydroponic methods, we hope this transparency will open some doors to deeper understanding.

[1] https://www.greenhousegrower.com/crops/the-top-fresh-produce-greenhouse-growers-in-the-u-s/, https://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=101510

HYDRO 101

Why Grow with Hydro?

As a resource-intensive approach that requires specialized training, hydro is not appropriate for all agricultural applications. The best fit tends to come from one or more of these advantages:

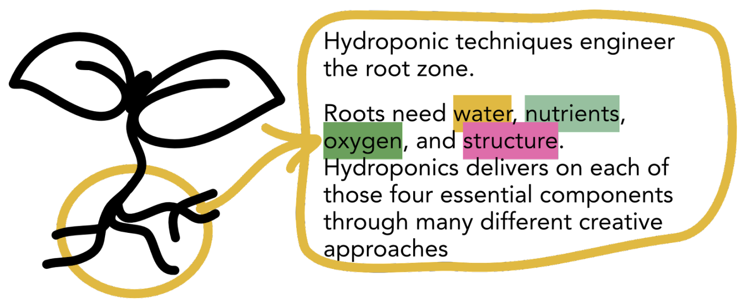
- efficient use of water and fertilizer
- start up time is short
- crops grow quickly, reliably, and uniformly
- possible anywhere, not dependent on good soil
- works well with controlled environment agriculture (CEA) like greenhouses

What Plants Grow in Hydro?

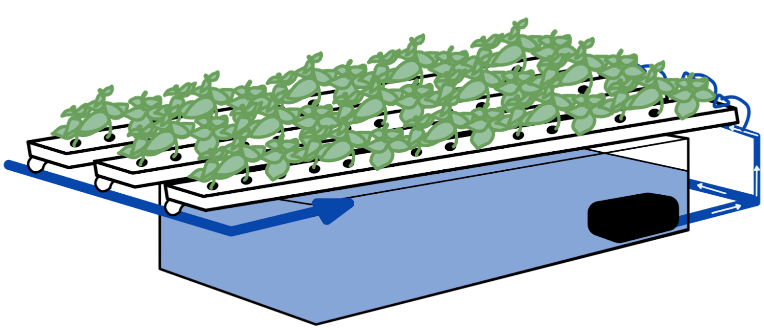
Technically, anything! Even a tree! For production purposes, quick growing and high value crops tend to work best. A few examples: tomatoes, cucumbers, lettuce, arugula, basil. At Brooklyn Grange, our main hydroponics crop is basil.

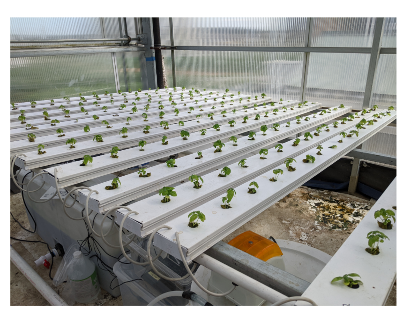
How Does it Work?

Hydroponics may be defined as a technique for growing plants in a nutrient solution without soil. The diagram on the right shows another way of thinking about it.



At Sunset Park Brooklyn Grange uses a type of hydroponics called Nutrient Film Technique (NFT). The crop is planted into 8 foot long channels with a constant supply of fertilized water. That water is then captured on the far end of the channels and returned to the reservoir. The diagram below shows how the water moves, right to left: nutrient water is pumped up into little tubes (small white arrows), down the channels, and then drains back into the reservoir (big blue arrow).





EVALUATING RESULTS

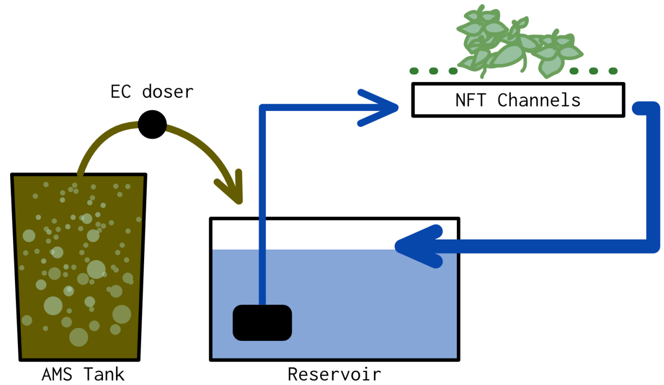
We are trialing three organically sourced fertilizers and grow media, sampling a range of product types and best practices. To compare these vastly different and biologically active inputs, product success will be judged according to the following criteria and metrics.

CRITERIA	METRIC
FERTILIZER	
Ease of use (odor, clogging, biofilter maintenance…)	Qualitative
Financial cost: labor, cost, additional infrastructure, etc	U.S. Dollars
Nutrient availability and stability	Water testing
pH stability	Water testing
Crop success: yield, speed of growth, pests	Yield (lbs) and logs
Crop success: health, saleability, flavor	Qualitative
Material origins	LCA Research
No negative impact on soil from fertigating effluent	Soil tests
GROW MEDIA	
Ease of use (watering, transplanting, cleanup, …)	Qualitative
Financial cost: material cost, labor, etc	Qualitative
Filtration burden	U.S. Dollars
Crop success: germ rate, health, speed of growth	Logs
Material origins	LCA Research
Compostability	Compost test

Filtration, while not an input, is critical to the successful operation of an aquaponics system, and we hypothesized for an organic hydroponic system as well. Guideposts for successful filtration include:

- Removal of solid detritus from the main water circulation system, such as biofilms, algae, roots, and small pieces of grow media.
- Maintenance is required no more than once per week.
- Successful cultivation of nitrifying bacteria, as measured by the stable conversion of ammonia NH_4^+ to nitrate NO_3^-

THE FIRST FLOP: WHAT IS MINERALIZATION?



We installed an Aerobic Mineralization System (AMS) to act as a biofilter before the first fertilizer trial. The AMS was a 30 gallon food-grade tank with a bubbler for aeration and a few gutter brushes for biofilter surface area. The diagram on the right shows how the AMS tank fit into our system. We thought AMS was fancy wording for a nitrogen converter, and that was our first big mistake! In practice, the AMS functioned more as a biodigester. Here's a breakdown of the vocabulary:

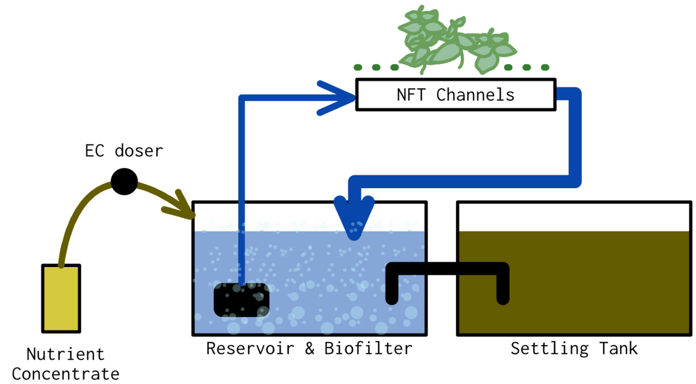
- Mineralization: Breakdown and conversion of organic molecules to ionic (mineral) nutrients, which can be taken up by plant roots. Mineralization is part of natural nutrient cycling in healthy soils. Some technologies can facilitate the conversion of specific nutrients, most notably nitrogen.
- Biofilter: Grows autotrophic bacteria that mineralize nitrogen. A biofilter mimics the nitrification step in the nitrogen cycle: conversion of ammonia (NH_4^+) → nitrite (NO_2^-) → nitrate (NO_3^-)
- Biodigester: Grows microbes that break down organic matter. Commonly used in the treatment of solid waste, to produce methane from farm organic matter, and in water treatment. Biodigesters can be aerated or not, which would foster the growth of aerobic or anaerobic bacteria respectively.

In this application, the main difference between a biofilter and a biodigester is how well solids are removed. If filtration is good enough, it's a biofilter: there won't be a food source for heterotrophic bacteria, and the nitrifying bacteria will have enough oxygen. If filtration is poor and organic solids build up, the heterotrophs will outcompete the nitrifying bacteria, and the result is an accidental biodigester. Organic solids include anything of biological origin you can see in water – bits of dead roots, algae colonies, particles of organic grow media.

In the case of our AMS tank, which was not inline with the main recirculation in the system, the solids were just fertilizer gunk and growing heterotrophic colonies! We weren't filtering the AMS at all, either before adding fertilizer, or as regular maintenance. Nitrification started off well but dropped off within a few weeks. Given what we now understand about biofilters and biodigesters, it makes perfect sense!

SECOND DESIGN: SETTLING FOR FILTERS

Besides the accidental biodigestion, the AMS approach was too dilute to use for dosing a hydroponic system. The 30 gallon tank ran out a few times per week, which is a lot of work to upkeep and makes the environment very unstable and unhealthy for the nitrifying bacteria. So we decided to try an in-line biofilter by adding an aeration manifold and surface area (scrunched up bird netting) to the reservoir. To address the solids issue, a second tank was added with a connection to the reservoir to siphon off and settle out solid waste. The picture on the right shows this second design. The nutrient level in the reservoir is maintained from a nutrient concentrate, instead of from a diluted tank.



In the spirit of good science and engineering, this design is also a flop! Why? We think a settling tank is most effective for solids that are heavy so they'll fall out of suspension quickly. Most of the solid waste in our organic hydro system is lightweight biofilms or small root bits – so the settling tank just jump-started the heterotrophs into some really nasty looking slime. The signs we observed through the first and second trials that the heterotrophs were winning:

- Water smells briney or swampy
- Filters and ¼" tubing clog with biofilm (see pics 1-2 below)
- Biofilm (heterotroph slime) is growing visibly on plant roots (see picture 3 below)
- Nitrification starts strong but tapers off after a few weeks.
- Basil plants indicate stress: consistently small, tough tissue, long internodes

1. 

2. 

3. 

MOVING FORWARD

There are three primary issues we are currently troubleshooting:

1. pH management
   During the first fertilizer trial, which used a product manufactured from fulvic acid and fermented vegetable matter, the pH in the reservoir was consistently too low (~4.0-4.5). The carbonate hardness (ppm CO_3 which is consumed by nitrifying bacteria) also quickly dropped to zero. By the end of this trial, we found a good way to add CO_3 and buffer the pH was to spread out a thin layer of crushed oyster shells in a channel without plants. It's easy to find as a chicken feed supplement, and flow through the channel can be adjusted according to how much calcium or carbonate is needed.

   The second fertilizer trial, which is using a locally produced product made from food waste, needed pH to be lowered instead of raised. Unfortunately, we have been finding that organic acids like citric acid are a food source for heterotrophic bacteria. This issue ties into the next issue we are troubleshooting. If we aren't able to resolve it, we will probably switch to phosphoric acid moving forward.

2. Heterotrophs are outcompeting nitrifying bacteria due to solids buildup. Here are some strategies we are trying:
   - Flush all ¾" risers, 2" pump lines, and 4" drain lines every week.
   - Add a strainer to the drain line that won't back up.
   - Install a disc filter on the pump, replacing a screen filter.
   - Fully change from the reservoir every 2-3 weeks. Pump water into a second tank and ferment: allow the bad-guy heterotrophs to grow unchecked until they run out of food and die off. Filter this reconditioned water and use it to make up water in the reservoir. This is an exciting idea but still needs some research, and some trial and error, to back it up!

3. Experimenting with the right ways to approach these issues is taking a lot of trial and error and is concurrent with fertilizer trials. This troubleshooting is important to achieving the project's goals, but it doesn't give the fertilizers a fair trial. Luckily a second trial for each fertilizer to negate seasonality bias was already in the project schedule. Meanwhile, we are treating all data collected from these first trials as useful for informing design decisions, but not determinative of the product's utility.

BEYOND THE SCOPE

A strong argument in favor of hydroponic farming is the speed a system can be installed and growing produce year round. It's also not dependent on access to healthy soil or large quantities of water. Despite its strengths, modern hydroponics as practiced in the Global North is constrained by its own design philosophy: maximize control to maximize growth. It's important to remember the broader context as global challenges around food and climate research fuel urgency for research like this project.

The goal in hydroponics is control to optimize inputs to produce a consistently perfect crop. The drawback? Control is resource intensive. Hydroponic systems are usually installed indoors, in what's called Controlled Environment Agriculture (CEA). For example, Brooklyn Grange's hydroponic systems are in greenhouses. Running a hydroponic greenhouse requires a lot of resources:

- The structure itself, metal and plastic whose end-of-life is usually not considered
- Intensive HVAC systems and supplemental lighting, which is the largest energy draw within the farm department at Brooklyn Grange
- External inputs of questionable origin, which the subject of this research project

Hydroponics is a quick fix technology, a lot of stuff and energy for a rapid turnaround. There are times when those advantages make hydroponics the most appropriate technology: the least cost alternative to getting fresh vegetables to large numbers of people. That does not make it "sustainable." Like any hot topic in sustainability or healthy food, consumers face constant greenwashing, and hydroponics is no exception. Sometimes to break the patterns imposed by an existing industrial complex such as CEA, or the approach of conventional Green Revolution agriculture, we need to cast a wider net.

What is hydroponics? At the root, it is a creative approach to irrigation and fertilization. Highly engineered irrigation systems suited to local ecology have been developed around the world by many indigenous peoples. (Raised field agriculture such as chinampas are commonly cited as a precursor to aquaponics, though it's arguably more advanced; they can grow a diversity of calorie and protein crops.) This is an amazing example of convergent technological evolution, and a sign that there is something to this idea of soilless farming. Hydroponics will have a role in creating healthy, local, and resilient food systems, but there is a lot of learning to do first.

If you have ideas or questions about anything related to this progress report, I would love to connect with you! Email me at maya@brooklyngrangefarm.com.

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