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

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

Introduction video for this Kratky project.

#### The goals

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

#### The setup

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



The experimental Kratky setup. You can see the project box

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

#### The measurements

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



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

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

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

#### Conclusion

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

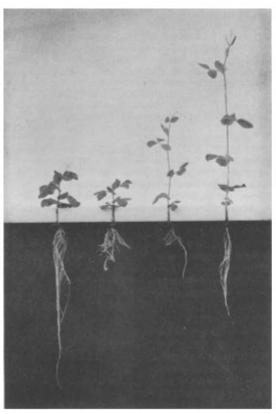
I will continue to share updates of this project in both my blog and <a href="YouTube channel">YouTube channel</a>.

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

### Kinetin, a powerful hormone for flowering plants

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

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



No Benzyladenine

No Benzyladenine

Log (Molar Concentration)

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

Fig. 5. Comparative inhibitory effects of kinetin and N<sup>6</sup>-benzyladenine on the height of the 'Alaska' pea.

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

#### The effects of exogenous kinetin

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

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

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

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

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

#### Kinetin foliar sprays

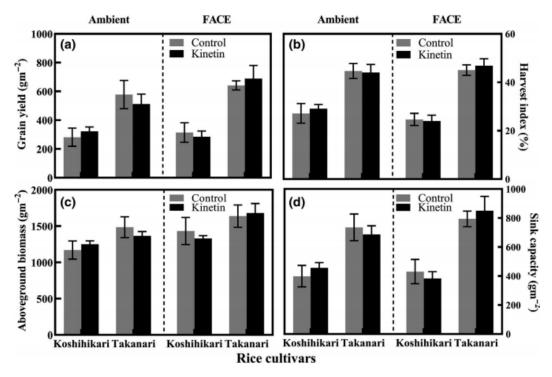
The mode of application makes a big difference as well. While

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

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

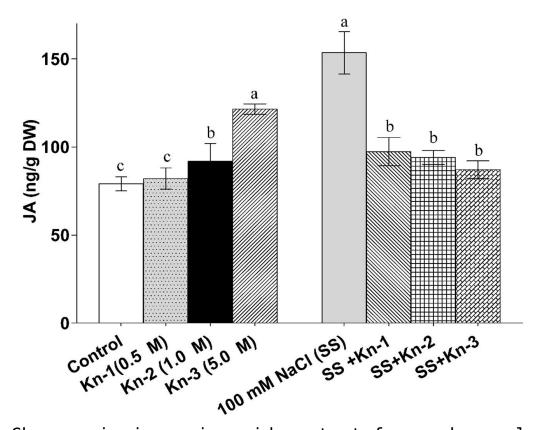
#### **Environmental conditions**

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



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

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



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

#### Conclusion

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

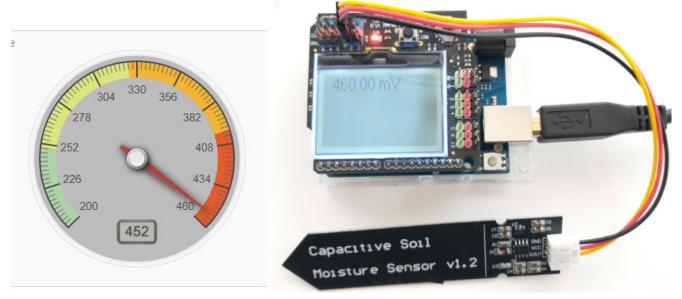
If you want to use kinetin in your crop, start with a foliar

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

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

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

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



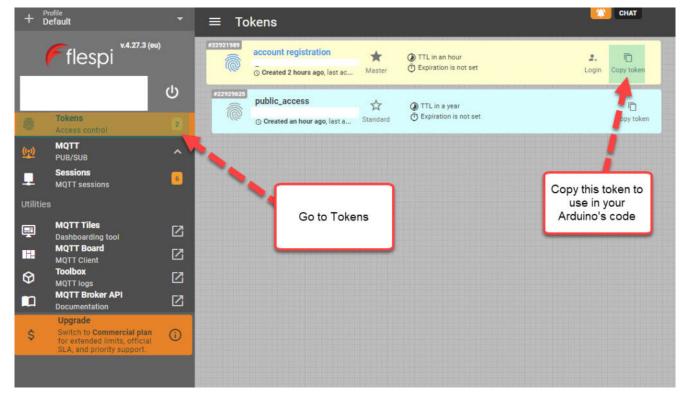
An Arduino Wifi Rev2 connected to a moisture sensor, transmitting readings to an MQTT server hosted by flespi that generates an online dashboard

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

#### What you will need

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

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



Copy the token from the "Tokens" menu in flespi

#### Libraries and code

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

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

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

```
"mqtt.flespi.io"
#define MQTT BROKER
#define MQTT PORT
                       1883
U8G2 ST7565 NHD C12864 F 4W SW SPI u8g2(U8G2 R0, /* clock=*/
13, /* data=*/ 11, /* cs=*/ 10, /* dc=*/ 9, /* reset=*/ 8);
float capacitance;
WiFiClient wifiClient;
MgttClient mgttClient(wifiClient);
// checks connection to wifi network and flespi MQTT server
void check connection()
{
  if (!mqttClient.connected()) {
    WiFi.end();
   WiFi.begin(SECRET_SSID, SECRET_PASS);
    delay(10000);
    mqttClient.setUsernamePassword(FLESPI TOKEN, "");
    if (!mqttClient.connect(MQTT BROKER, MQTT PORT)) {
      Serial.print("MQTT connection failed! Error code = ");
      Serial.println(mqttClient.connectError());
      delay(100);
    }
  }
}
void setup() {
  pinMode(LED_BUILTIN, OUTPUT);
  pinMode(4, OUTPUT);
  Serial.begin(9600);
  analogReference(DEFAULT);
  check connection();
}
void loop() {
  String moisture_string;
  check connection();
  // read moisture sensor, since this is a wifiRev2 we need to
set the reference to VDD
  analogReference(VDD);
```

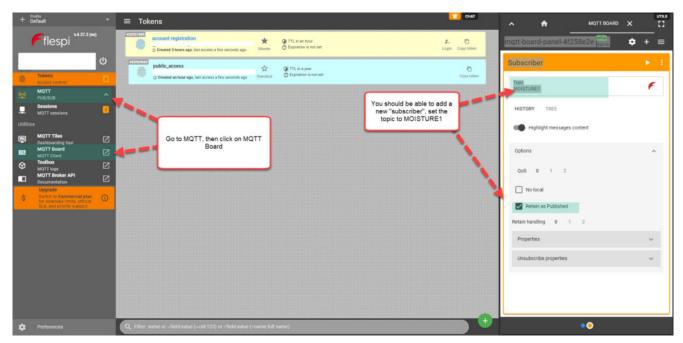
```
capacitance = analogRead(ANALOG PORT);
  // form the string we will display on the Arduino LCD screen
  moisture string = String(capacitance) + " mV";
  Serial.println(moisture string);
  // send moisture sensor reading to flespi
  mqttClient.beginMessage("MOISTURE1");
  mgttClient.print(capacitance);
  mgttClient.endMessage();
  // the LCD screen only works if I reinitialize it on every
loop
  // I also need to reset the analogReference for it to
properly work
  analogReference(DEFAULT);
  u8g2.begin();
  u8g2.setFont(u8g2 font crox3h tf);
  u8g2.clearBuffer();
                              // clear the internal memory
   u8g2.drawStr(10,15,moisture string.c str()); // write
something to the internal memory
  u8q2.sendBuffer();
                               // transfer internal memory to
the display
  delay(5000);
}
```

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

#### Configure Flespi

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

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



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

#### Create the Dashboard

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



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

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

#### Conclusion

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

# How to choose the best hydroponic bucket system for you

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

#### The Kratky bucket

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



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

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

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

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

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

#### The bucket with and air pump

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

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



A typical air-pump bucket system growing kit

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

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

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

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

#### The Dutch bucket system

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

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



A commercial Dutch bucket hydroponic system

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

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

#### Conclusion

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

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

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

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

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

## Arduino hydroponics, how to go from simple to complex

Hydroponic systems offer a great opportunity for DIY electronics. In these systems, you can monitor many variables, gather a lot of data, and build automated control systems using this information. However, the more advanced projects can be very overwhelming for people new to Arduinos and the

simpler projects can be very limiting and hard to expand on if you don't make the right decisions from the start. In this post, I'm going to talk about the easiest way to start in Arduino hydroponics, which materials and boards to buy, and how to take this initial setup to a more complex approach with time.



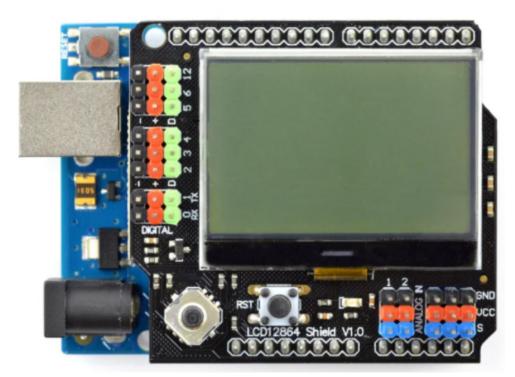
The Arduino Wifi Rev2

#### Buy the right Arduino

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

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

For people new to Arduino, it is easier to avoid sensors that require soldering or protoboards and go with plug-and-play approaches. My all-time favorite is the "Gravity" system created by DFrobot, which uses shields that expose quick access connectors that you can use to plug-in sensors. My recommendation is the <a href="LCD12864">LCD12864</a> 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  $\mathrm{CO}_2$ , 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 <a href="from uFire">from uFire</a>, which have a lower cost, are properly isolated, and are easy to use. The <a href="hydroponic kit collection">hydroponic kit</a> collection, offers all the sensors and boards you require, in rugged industrial quality configurations, to build a hydroponic monitoring station.

#### Next step, simple control

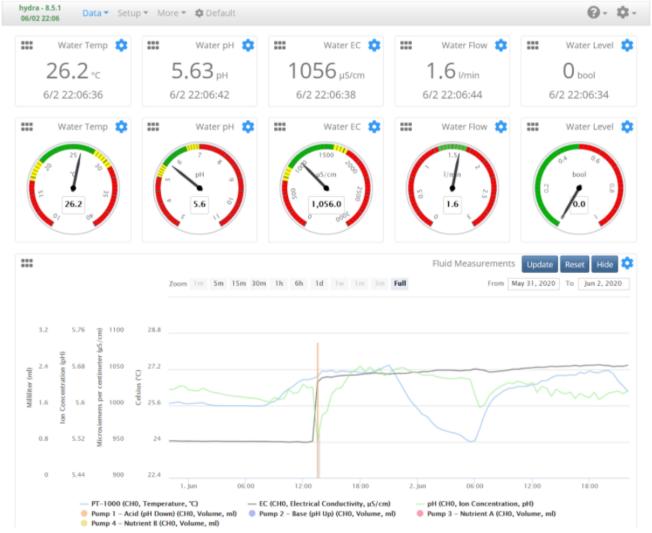
The next step in complexity is control. You can use a Gravity relay to switch a light or timer on or off. You can also use a simple dead-band algorithm to attempt to control your temperature and humidity values by using relays to turn

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 <a href="this shield">this shield</a> 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

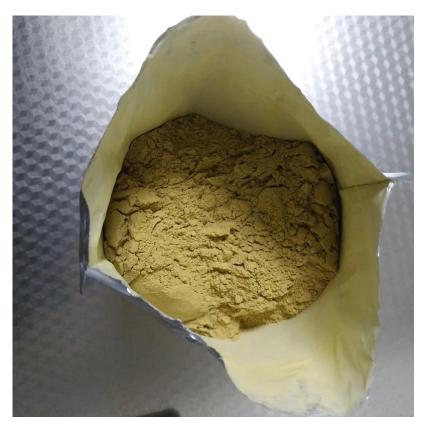
Arduino in hydroponics does not need to be complex. Your first project can be a simple temperature/humidity monitoring setup and you can evolve to more complicated projects as your understanding and proficiency grow. If you select a powerful and feature-rich Arduino from the start, you can use the same 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<sub>2</sub>FeEDTA, 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<sub>2</sub>EDTA-2, H<sub>3</sub>EDTA-1, and finally H<sub>4</sub>EDTA. 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<sup>2+</sup> 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

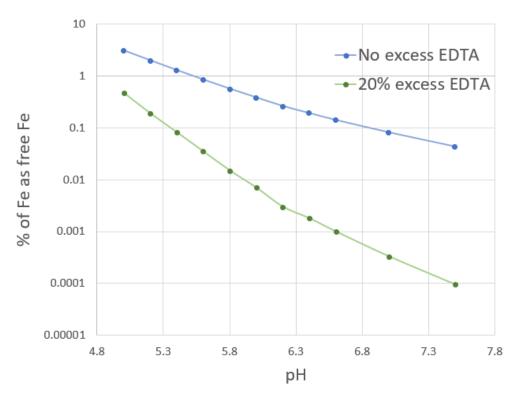
Since free heavy metal ions are the ones that can precipitate and become unavailable, what we desire is to lower the amount of free heavy metal ions in solution and increase the percent of chelated ions. Whenever you put a chelated heavy metal source in solution, like Na<sub>2</sub>FeEDTA, the chelate 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 lppm of Fe from Na<sub>2</sub>FeEDTA 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<sub>2</sub>FeEDTA 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 Fe²+, 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.

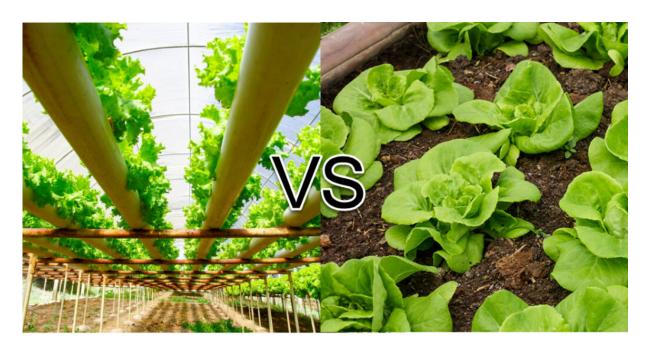
#### Conclusion

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
<u>3</u>	Lettuce	Nutrient density	hydro
4	Soybean	Nutrient density	hydro

<u>5</u>	Strawberry	Nutrient density	hydro
<u>6</u>	Strawberry	Nutrient density	hydro
<u>6</u>	Raspberry	Nutrient density	soil
<u>7</u>	Strawberry	Nutrient density & taste	hydro
<u>7</u>	Raspberry	Nutrient density & taste	hydro
<u>8</u>	Strawberry	Nutrient density	soil
<u>9</u>	Strawberry	Quality	soil
<u>10</u>	Cucumber	Quality	hydro
11	Pepper	Antioxidants	hydro
<u>12</u>	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 Perlite Pumice Soil	2343 <sup>a</sup> 2105 <sup>ab</sup> 2178 <sup>ab</sup> 1762 <sup>b</sup>	2291 <sup>a</sup> 2030 <sup>a</sup> 2134 <sup>a</sup> 1640 <sup>b</sup>	55 <sup>b</sup> 69 <sup>ab</sup> 51 <sup>b</sup> 123 <sup>a</sup>	$109.3^{a}$ $110.3^{a}$ $112.9^{a}$ $100.0^{a}$	113.9 <sup>a</sup> 115.7 <sup>a</sup> 118.9 <sup>a</sup> 116.3 <sup>a</sup>	41.6 <sup>a</sup> 28.0 <sup>b</sup> 35 7 <sup>b</sup> 34.2 <sup>b</sup>	21.3 <sup>a</sup> 19.8 <sup>a</sup> 19.3 <sup>a</sup> 17.6 <sup>a</sup>	20.1 <sup>a</sup> 17.3 <sup>a</sup> 17.9 <sup>a</sup> 14.1 <sup>b</sup>	1.2° 2.5° 1.4° 3.5°

Yield comparison for zucchini grown under a variety of different soilless media and soil. Taken from <a href="here">here</a>.

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 lowimpact, 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.

<u>Coco coir</u> 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 predigested 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.

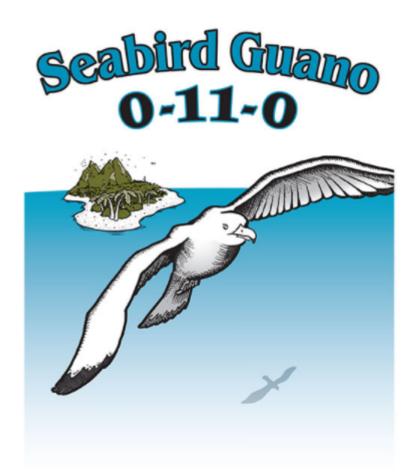
#### Conclusion

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 biostimulants, 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).

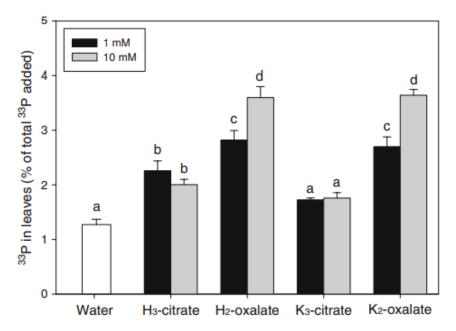
However, these sources do not only contribute phosphorus but will also contribute a variety of different substances that need to be taken into account when considering them for use. In the case of CSL, very high lactate and organic nitrogen levels imply that you will need to prepare an appropriate compost 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 <u>rock phosphates</u> and <u>bone meal</u>. 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  $150\,\text{mg/L}$  ( $567\,\text{mg/gal}$ ) 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  $40\,\text{mg/L}$  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.