Five reasons why a dedicated hydroponic testing room is a great idea

Most commercial hydroponic setups completely lack testing environments. The most common reason for this is that commercial crops are meant to produce revenue and a testing environment means dedicating space, time and money into something that might not be as productive as the rest of the production facility. Furthermore a testing room implies that you will need to create a completely independent setup and hire someone who knows how to do research in order to ensure it is both adequate and fruitful. Although many people believe this not to be worth it today I want to talk about the five most important reasons why I consider that a testing room is something incredibly useful to have as a part of your commercial growing facility and why getting one will probably pay off greatly for you going forward.

Testing product changes. Perhaps the first and most direct benefit to having a testing room is to ensure you can test product changes. It may be the case that your supplier for some particular fertilizer product or additive has ran out and you now want to test a new product to replace it. It may also be that you want to test how a product does compared to what you generally use but you don’t know if it does better or worse. Most growers are afraid of change because making facility-wide changes that won’t work could have huge financial consequences. A testing room ensures you can test safely and then roll-out changes slowly without having to risk your entire crop cycle to find out.

Optimizing what you currently have. Change is very rare across

commercial facilities because growers understandably want to preserve their current results, even if some better results by making some change would be possible. This constraints growers from making incremental changes that might make their crops significantly more productive. By having a testing room you can optimize the setup you already have by making adequate research into optimizing things such as environmental or nutritional factors.

Trying potentially game-changing modifications from academic research papers. There are many papers published each year on how to increase the yields of hydroponic crops. Some of these papers offer somewhat risky and controversial changes that might not transfer well across species. However if something gives you the potential to increase your yields by say, 50%, it might definitely be worth trying across a testing setup. Obviously these things are too risky to try across an entire facility but a testing room would be perfect to help you try these new and exciting modifications, potentially giving you a huge edge versus all the other people who will never try this.

Try new plant varieties. Usually growers try new plants without having a clear idea of how productive they are going to be under their growing setup. This means that you introduce a new variety with a huge question mark regarding its productivity and potentially financial benefit or cost. A testing room provides you with a risk-free way to test how a particular plant variety will perform under the exact conditions in your facility, potentially allowing you to make far less risky decisions when it comes to making planting changes in your facility.

Research new ideas. A final benefit you can get from a testing room is that you can research your own new ideas. With adequate experimental design even a small room with just 10 plants can be used to test some ideas to see how they affect

plant growth. This means that you can develop your own in-house growing modifications that will make it much harder for others to compete with you. For example if you developed a secret foliar additive in your growing facility it would allow you to only use this for your own crops, without the industrial secret ever being used by your competitors.

Of course there are many other advantages to testing rooms but the above are just some of the wonderful things you'll be able to do if you have a testing room and someone trained in scientific research who can help you design experiments and get the most out of it. A testing room also doesn't need to be huge and even starting out with 10 plants can be a huge step in taking your commercial growing facility to the next level.

The use of phosphites in plant culture

Plants normally get most or all of their phosphorous from inorganic phosphorus sources. Most commonly these sources are monobasic or dibasic phosphate ions ($H_2PO_4^-$ and HPO_4^{-2}), which are naturally formed from any other phosphate species at the pH values generally used in hydroponics (5.5-6.5). However these are not the only sources of inorganic phosphorous that exist. Phosphite ions – which come from phosphorous acid H_3PO_3 – can also be used in plant culture. Today we are going to talk about what phosphite does when used in hydroponics and why it behaves so differently when compared with regular phosphate sources. In research P from phosphate is generally called Pi, so I will follow this same convention through the rest of this post. A good review on this entire subject can be

found here.

The role that phosphite (Phi) plays in plant nutrition and development has now been well established. Initially several people claimed that Phi was a better P fertilizer than Pi so researchers wanted to look into this to see if Phi could actually be used as an improvement over Pi fertilization. However research was heavily disappointing, studies on lettuce (here) , spinach (here), komatsuna (here) as well as several other plants showed that Phi fertilization provides absolutely no value in terms of P nutrition, meaning that although plants do absorb and process the Phi it does not end up being used in plant tissue to supplement or cover P deficiency in any way. Furthermore there are some negative effects when Phi is used in larger concentrations (as those required for Pi) so it quickly became clear that Phi is not a good fertilizer at all.

Why should anyone use Phi then? Well, research started to show that some of the earlier positive results of Phi fertilization were not because it was covering Pi deficiencies but mainly because it was offering a protective effect against some pathogens. Research on tomatoes and peppers and other plants (here and here) showed that phosphites had some ability to protect plants against fungi with plants subjected to Phi applications showing less vulnerability to the pathogens. However the evidence about this is also not terribly strong and a few papers have contested these claims.

Those who say that Phi is not mainly a fungicide claim that positive results are mainly the effect of Phi acting as a biostimulant (here). These groups have shown through research across several different plant species, including potatoes,

onions, lettuce, tomatoes, wheat, oilseed rape, sugar beet and ryegrass that foliar or sometimes root applications of phosphites consistently yield some positive effects, meaning that there is a strong biostimulant effect from the Phi that is not related to either P nutrition or a fungicidal effect. A recent review looking at the overall biostimulant effects of Phi (here) shows how researchers have obtained evidence of biostimulation in potatoes, sweet peppers, tomatoes and several other species (the images in this post were taken from this review). The different studies mentioned in the review show increases in quality and even yields across these different plant species (see tables above).

While we know that Phi is not a good source of P nutrition and we know it can help as a fungicide in some cases it is clear now that under enough Pi nutrition Phi can provide some important biostimulating effects. Negative effects from Phi seem to be eliminated when enough Pi nutrition is present so rather than be thought of as a way to replace or supplement P nutrition it should be thought of as an additive that has a biostimulating effect. Phi may become a powerful new tool in the search for higher yields and higher quality, while not serving as a replacement for traditional Pi fertilization.

Five things you should know when mixing your own hydroponic liquid nutrients

Many hydroponic growers – especially large scale ones – can benefit greatly from mixing their own custom nutrients. Not only can this save money in the thousands of dollars per month

but it can also give you an unprecedented degree of control when compared with store-bought nutrients. On today's post I am going to write about five important things you should know when mixing your own nutrients so you can avoid many common problems that can arise when you start preparing your own stock solutions.



More concentrated solutions are not always better. When you prepare a concentrated liquid you would usually want to go with the highest possible concentration factor so that you can prepare as much final nutrient solution as possible with as little stock solution as possible. However trying to get into higher concentration factors (1:400-1:500) can cause important issues due to the solubility of the salts used and the temperatures the stock solution will be exposed to. It can also cause high inaccuracies with variable injector setups since the dilutions will be much smaller. For starters go with a 1:100 concentration factor and only start going higher when you get more experience. If you're using injectors I would generally avoid a range higher than 1:250 unless you do more extensive calibration procedures with your injectors.

Impurities can cause important problems. Some salts can come with significant levels of impurities – sometimes mainly additives – that can cause substantial issues when preparing your nutrient solutions. Lower quality grade salts – mainly those used for soil fertilization or those that are OMRI listed and come straight from mining with no refining – can generate problems within your mixing process. These problems range from insoluble left-overs in tanks to toxic amounts of some micro elements. To ensure you get the best possible results use greenhouse grade fertilizer salts and try to avoid sources of salts that are OMRI listed. Synthetic sources that have been heavily purified are your best bet in ensuring the best possible results.

Use slightly acidic deionized water to prepare the solutions. Most water sources in Europe and the US are very heavy in carbonates an therefore inappropriate for the preparation of concentrated nutrient solutions as these ions can cause salts to precipitate when preparing concentrated solutions. To fix this issue the best thing would be to use distilled water but – since this is often not an option – the next best thing is to use reverse osmosis water and add a bit of acid (0.5mL/L of nitric acid, other acids may cause other problems) per gallon of concentrated solution. This will ensure that everything gets dissolved and will eliminate the carbonates that can be naturally present within the water. *Of course never, ever use tap or well water to prepare concentrated hydroponic solutions*.

Salts take up volume, take that into account. A very common mistake when preparing solutions is to just add the salts to the final volume of desired stock solution to prepare. This is a mistake since the salts also take up volume. If you want to prepare 1 liter of concentrated solution and you need to add say, 100 g of potassium nitrate, adding 100g of potassium nitrate to 1L of water would generate a solution with a final volume greater than 1L. To avoid this problem always add the salts to half the volume of water and, after the salts have dissolved, complete to the final volume of desired solution.

Add salts from the smallest to the largest quantities. When you prepare hydroponic solutions it is often better – especially when you're starting – to add salts from the smallest to the highest amounts needed. If you make a mistake at some point then you will minimize the amount of mass of salts that has been wasted due to this fact. If you make a mistake adding a micro nutrient you will only lose a small amount of the other micro nutrients instead of losing a huge amounts of macro nutrients due your order of addition. It is also true that the substances that are added in largest quantities are commonly nitrates and these salts have

endothermic dissolutions – meaning they cool solutions upon addition – so it is better to add them last so that they can benefit a bit from the heat generated by the dissolution of the other salts.

The above is not an exhaustive list of pointers but it should save you from some important trouble when preparing your own initial nutrient solutions.Although some of these points may seem obvious to those that have experience preparing their own solutions they may prove invaluable to those who are just starting their journey in concentrated nutrient preparation.

Humic acids in hydroponics: What is their effect?

Plants and microorganisms affect the substrates in which they grow in many ways. If you start growing plants in an inert substrate – with nutrient applications of course – you will notice that the substrate's chemical composition will start to change with time and it will start to get enriched in carbon containing substances. As plants and microorganisms grow, thrive and die, some of the chemicals that made up their cells end up enriching the substrate they grow on. This process – whereby organic materials from living organisms become part of a substrate – is what generates the soils around us. One of the most prevalent class of components in this organic material, is what we call humic acids.

Humic substance chemical properties.

Humic acid is not a single substance but a wide range of

substances that are created as a product of plant and microorganism decomposition. This is why you often hear people talk about “humic acids” instead of simply “humic acid”. They are called “acids” because the humic substances contain molecules that have groups that resemble those found in phenol and vinegar. They are also differentiated from fulvic acids in the fact that they are only soluble at basic pH values while fulvic acids are generally small enough molecules to be soluble across most of the pH spectrum. Since humic acids are a very important component of enriched soils and can be used in soiless culture, people have started using them as supplements in soiless and pure hydroponic culture.

When talking about the effects of humic acids it is worth mentioning that since we’re talking about a group of molecules – not a single substance – effects are generally dependent on the source of the humic acid used. For example you can find a study on tomatoes here where two different sources of humic acids – from peat and leonardite – were used to grow tomatoes. The study shows a clear difference between both with the first only stimulating root growth while the second stimulated both roots and shoots. However in both cases there was an increased iron availability to plants, although the mechanism for this was not established.

Tomato plants inoculated with root rot at different humic acid application rates

In plants like gerberas humic acids applied at 1000 ppm can offer increases in harvested flowers of up to 52% (see here), somewhat positive effects can also be seen in tomatoes across the literature with most studies showing increases in yields and mineral contents (see here), reports of positive effects on gladiolus have also been published (here). Since the 1990s there has been a somewhat established understanding of some

general beneficial effects for humic acid applications, it is well established that they can prevent and eliminate micro nutrient deficiencies due to their abilities to increase their availability(see here). The literature is also quite consistent in that the largest effects are often seen on root growth rather than on shoot growth or mass. There are however some types of humic acids that have showed higher increases of shoot mass, for example in an article studying humic substances derived from municipal waste on barley this was the observed effect. For some plants however – despite these beneficial effects – increases in yields in hydroponic culture are not evident (see here and here). A look at the effect of a humic acid source on several different plant species can be found here.



Effect of humic acid, bacteria and lactate applications on tomato plants.

It is worth noting that humic acid applications are also not limited to the root zone. Since humic acids can enhance the absorption of some nutrients they can also be applied in foliar sprays. Experiments on strawberries (here) showed that an application of 1.5-3ppm of humic acids led to an increase in the quantitative and qualitative properties of the fruits. Combinations of humic acids with other biostimulants are also common. For example a combinations of lactate, humate and beneficial bacteria was tested on tomatoes (here) but the experiments showed that the effect could be stimulating or inhibiting depending on the particular conditions, even though most combinations were beneficial.

With the high variability between humic substance origins, application rates and effects it is very hard to say whether humic acid applications will definitely help your crops in terms of yields. For almost all humic acid sources it is probably warranted that micronutrient absorption will be

somewhat augmented due to their ability to chelate these nutrients, but only if the nutrients are not efficiently chelated already. This sole ability might lead to crop improvements if deficiencies are present but improvements in yields will strongly depend on humic acid substance origin and particular properties. However humic acids do seem to lead to general product quality improvements and since negative effects are rare there seems to be no harm in carrying out field tests to determine if their use is worth it for your particular crop.

How to prevent problems with powdery mildew in hydroponic crops

One of the worst problems you can get in a hydroponic crop is mildew. Year after year I see growers lose significant amounts of production due to this disease within a variety of different crops. Powdery mildew reduces yields, stunts plants and – if contracted early on – will possibly cause a complete loss of your crop. It is generally hard to control once it gets in and it will expand like wildfire through any commercial growing operation. Today we will be discussing how to actually prevent mildew from ever appearing – without using toxic fungicide applications – and why prevention can play a huge role in ensuring you never have to face this problem in the first place.



Fungal spores are generally carried by the wind and by

insects, making it very hard for a crop to avoid ever coming into contact with the pathogen. Wild plants or plants from other commercial crops close to you will most likely have the disease and millions of spores will get in the air and eventually reach your plants. It is only a matter of time till the powdery mildew reaches your crops – almost impossible to prevent – so you must make sure that your plants are strong enough to prevent the pathogen from taking hold.

There are two main factors that affect whether powdery mildew will infect your plants. The first is plant strength and the second is the environment. If one of these two is not at its best then your plants will fall prey to this fungal disease. Neither strong plants under bad environmental conditions nor weak plants under ideal environmental conditions will be safe from the disease. So what can we do to ensure our plants are healthy and our environmental conditions are safe?

One of the proven methods to make plants strong against fungi is silicon. Potassium silicate applications – as soil drenches or foliar sprays – have proven to increase disease resistance across several studies (see here and here for examples). But other innovative approaches using other forms of silicon – for example nanometer sized silica crystals – have also yielded good results. In this and this studies it was clearly shown that other forms of silicon – besides silicate – could also help in preventing fungal disease. This might be preferred in some cases as these forms of silicon can be far more stable and easier to store/apply compared with options like potassium silicate.





However silicate applications are no miracle. If your environmental conditions are not set properly the silicate applications will be useless. This is the reason why some

growers say that silicate does nothing against disease, because an environment that's favorable for fungi can basically nullify the protective action of supplemental silicon. This was demonstrated by cucumber growers who had a lot of success with Si supplementation in Canada to prevent fungal diseases, but failed to reproduce this success in Florida. A study about this difference revealed that the higher temperatures in Florida negated a large part of the benefits from silicon supplementation. If you want silicon to work against disease better stay in the 20-25°C range.

Other microorganisms can also be of great help in preventing powdery mildew. If a leaf is already colonized by beneficial fungi or bacteria it will be much harder for a pathogen to get in. Several species of microorganisms have been studied in this regard. Fungi like Tilletiopsis have shown to prevent and control the disease (see here), other microbes have also been studied in conjunction with silicon (see here and here), showing beneficial effects. Fungus like Trichoderma harzianum and bacteria like bacillus subtilis have also shown induction of systemic resistance against fungal diseases (see here, here and here). The two images above were taken from this study.

Friendly chemical solutions are also available for the prevention of powdery mildew. Plant derived extracts, for example neem seed oil at 1% has shown to be a good agent for powdery mildew prevention in okra (see here). Substances like salicylic acid have also shown to trigger resistance to powdery mildew in plants like peas (see here).

There are also additional alternatives dealing with the environment that can make it difficult for fungi to colonize plants by attempting to make the environment more hostile for fungi. Spraying ozonated water has shown positive results in experiments with tomatoes (see here) as well as electrolyzed water in strawberries (see here). Keeping the environment

conditions within a proper range is also important, this paper shows you how environmental conditions affect powdery mildew disease severity in sunflower but the general features are applicable to most higher plants. As you can see in the image above – taken from this paper – disease severity increases with relative humidity. In general you will want to keep your relative humidity below 70% to avoid making the environment extremely friendly for fungi.

In the end there are many things you can do to keep your plants free of foliar fungal disease like powdery mildew. Use lower temperatures, control your relative humidity, do silicate and salicylic acid applications and use beneficial microbes. If you follow these steps you will forget that powder mildew ever existed!

Five important things to consider when doing foliar spraying

Foliar spraying is a true and tested way to increase yields and prevent issues in plant culture. Both soil and hydroponic growers have used foliar fertilizer applications to increase yields and prevent problems due to nutrient deficiencies during the past 50 years. However there is a lot of mystery and confusion surrounding foliar fertilizer applications, reason why this technique is often applied incorrectly or sub-optimally. Today I want to talk about 5 key pieces of

information to consider when doing foliar fertilization so that you can be more successful when applying it to improve your crop results and reduce deficiency problems. If you want to learn more about these factors I suggest you read the following reviews on foliar feeding (here, here and here). Second table in this post was taken from this study on wheat.

Foliar fertilization is not root fertilization. A usual problem when doing foliar fertilization is to think that the same products can be used for leaves and roots. When you want to increase your crop yields using foliar fertilization you should definitely not use the same products and concentrations you use for soil. There are for example some chemical substances that you would never want to apply to the roots that have actually shown to give better outcomes in leaves. A good example is calcium chloride which is a huge mistake in root fertilizers but a great choice when doing foliar fertilization.

Foliar fertilizers should generally be much more concentrated. When people apply foliar fertilization they usually apply much lower concentrations because they are afraid of burning leaves. Although this can certainly happen if the foliar fertilizer is badly designed research has shown that the best results are obtained with much higher concentrations than what you generally use for the roots. For example when you apply an iron foliar fertilization regime you generally use a concentration of 500-1200 ppm of Fe while in root applications you only very rarely go beyond 4-5 (most commonly 1-3 ppm). Usually concentrations in foliar fertilizers will be much higher and if the fertilizer is correctly designed this will give much better results. The graph below (taken from the first review linked above), shows some of the most commonly used fertilizer concentrations.

Surfactants are very important (don’t use dish washing soap!). Leaf coverage is very important in foliar applications because you want the fertilizer to be evenly spread across the entire leaf not “clumped” into drops due to surface tension. Many people have trouble with nutrient burn due to bad fertilizer design that causes inadequate leaf coverage. However all surfactants are not created equal and ionic fertilizers are very undesirable for this task due to their interaction with leaf tissue and fertilizers. Due to this reason you should NOT use something like dish washer liquid soap but a proper non-ionic surfactant like a polysorbate. The surfactant will be a very important part of your foliar fertilizer formulation.

Timing is also critical. The time when you do your foliar sprays applications is also very important for optimal results. In general you want the leaf stomata to be open and the vapor pressure deficit to be lower so the best time to do foliar spraying is usually during the afternoon after temperatures have dropped significantly. For most time zones this usually means sometime after 3PM. Doing foliar applications sooner can lead to much larger stress due to a higher vapor pressure deficit – risking burns as well – while doing it later leads to less efficient absorption due to the stomata being closed. If applying the spray at this time is not possible then early morning often works as well. Make sure you measure your daily temperature/humidity fluctuations to ensure you don’t do foliar sprays at a high VPD.

Couple adequate additives for yield increases. Research has shown that while nutrient foliar spraying can enhance yields significantly under sub-optimal root feeding conditions if the root concentrations are already optimal – as in a well managed hydroponic crop – it is hard for simple nutrient foliar spraying to provide a lot of benefit. However there are several biostimulants that are poorly absorbed through the

root zone that can give you much better results when used as foliar sprays. Additives like salicylic acid and triacontanol can make sure that your nutrient foliar spray gives you maximum additional benefits.

As you can see there is a lot to the design of an adequate foliar spray. You must consider that the substances you use need to be fit to the purpose – not necessarily the same as for root applications! – and that your concentrations, surfactants, additives and application times are adequate. Now that you are aware of these factors you should take them into account when designing your next round of foliar spraying for your crops.

Creating a robust pH/EC monitor for hydroponics using Atlas probes and an Arduino

A few months ago I talked about how you could build a simple sensor station for your hydroponic projects using an arduino (see here). However this small project used the relatively cheap – but I have found not very robust – pH/EC probes and boards from gravity which makes it a poorer choice for a more professional project aiming to constantly monitor the pH/EC of a production hydroponic setup. Today I am going to tell you how you can build a dedicated pH/EC monitor using the robust pH probes from Atlas, which also have several important advantages we will be discussing within this post. *I would also like to point out that Atlas is not paying me anything to write this post, I write just because of my experience using their probes.*

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The pH/EC probes from gravity have several problems when looking for a robust sensing setup. The first issue they have is that the probes are not rated for constant immersion, so they are damaged if you place them within solution the whole time which is probably what you want to do within a production hydroponic setup. The second issue is that the boards require cable connections to the Arduino which introduces a significant amount of noise that can causes problems with measurements. Due to poor isolation there can also be issues with the gravity boards when measuring EC/pH at the same time. To overcome these issues we can use probes and boards from atlas which have the advantage of having no cable connections to the Arduino – connections are through pins directly – plus the probes are rated for constant immersion and are much more robust. These are the things we would need to build this project:

- Arduino UNO R3 – 23.90 USD
- LCD 12864 screen shield – 24.05 USD
- Mini tentacle shield – 85.00 USD
- pH kit from Atlas – 149.15 USD
- EC kit from Atlas – 195.71 USD
- Arduino headers – 12.99 USD

As you notice this sensor project is much more expensive than the sensor station I had discussed before, with a price tag of around 490 USD (not including shipping). However when looking for a robust setup you definitely should favor the additional expense as this will likely be paid off with much longer service times.

When you get the pH/EC kits the first thing you want to do is change your EZO boards (the small circuit boards that come

with them) to i2C mode so that you can use them with your mini tentacle shield. To do this follow the instructions here, follow the instructions in the “Manually switch between UART and I2C” section, use female jumpers to make this process easier. Note that you can use your LCD shield analogue 5V and ground pins when you need power within the process.

```
//Libraries
#include <U8glib.h>
#include <stdio.h>
#include <Wire.h>
#include <Arduino.h>

#define TOTAL_CIRCUITS 2

///---- variables for pH/EC tentacle shield ------- //

#define TOTAL_CIRCUITS 2

char sensordata[30];
byte sensor_bytes_received = 0;

byte code = 0;
byte in_char = 0;
int channel_ids[] = {99, 100} ;
// ------------------------------------------------ //

// EC values // CHANGE THESE PARAMETERS FOR EC PROBE CALIBRATION
#define EC_PARAM_A 0.00754256

//pH values // CHANGE THESE PARAMETERS FOR PH PROBE CALIBRATION
#define PH_PARAM_A 1.0
#define PH_PARAM_B 0.0

#define XCOL_SET 55
#define XCOL_SET2 65
#define XCOL_SET_UNITS 85

//-------------------------
```

```
U8GLIB_NHD_C12864 u8g(13, 11, 10, 9, 8);
float pH, EC;

//--------------------------

void draw() {
  u8g.setFont(u8g_font_04b_03);
  u8g.drawStr(0,11,"pH:");
  u8g.setPrintPos(XCOL_SET,11);
  u8g.print(pH);
  u8g.drawStr(0,21,"EC:");
  u8g.setPrintPos(XCOL_SET,21);
  u8g.print(EC);
  u8g.drawStr( XCOL_SET_UNITS,21,"mS/cm" );
}

void read_tentacle_shield(){

  for (int channel = 0; channel < TOTAL_CIRCUITS; channel++) {
    Wire.beginTransmission(channel_ids[channel]);
    Wire.write('r');
    Wire.endTransmission();
    delay(1000);

    sensor_bytes_received = 0;
    memset(sensordata, 0, sizeof(sensordata));

    Wire.requestFrom(channel_ids[channel], 48, 1);
    code = Wire.read();

    while (Wire.available()) {
      in_char = Wire.read();

      if (in_char == 0) {
        Wire.endTransmission();
        break;
      }
      else {
        sensordata[sensor_bytes_received] = in_char;
        sensor_bytes_received++;
      }
```

```
    }
    if (code == 1){
      if (channel == 0){
        pH = atof(sensordata);
        pH = pH*PH_PARAM_A + PH_PARAM_B;
      }
      if (channel == 1){
        EC = atof(sensordata);
        EC = EC*EC_PARAM_A;
      }
    }
  }
}

void setup()
{
    pinMode(13,OUTPUT);
    Serial.begin(9600);
    u8g.setContrast(0);
    u8g.setRot180();
}

void loop()
{

  digitalWrite(13, HIGH);
  delay(800);
  digitalWrite(13, LOW);
  read_tentacle_shield();

  u8g.firstPage();
    do  {
      draw();
    }
      while( u8g.nextPage() );
}
```

Once you have changed the EZO boards to i2C you can now plug everything into the arduino and upload the code into your arduino. Plug the EZO boards into the mini tentacle shield and then plug that shield into the arduino. You’ll notice that the

EZO boards make it impossible to plug the LCD screen directly on top – as the EZO circuits make the shield too tall – so you should use stackable headers to extend the connections so that you can plug the LCD screen on top without any problems. Make sure you download and install the U8glib library in your arduino IDE before uploading the code.

As with the previous code you'll notice there are variables called PH_PARAM_A, PH_PARAM_B and EC_PARAM_A within the beginning of the code that you should change in order to calibrate your probes. Follow the instructions about calibration I gave in the previous post in order to figure this out. Using the calibration solutions that come with your kits you'll be able to perform this calibration procedure. Whenever you want to calibrate your probes you should reset these variables to their original values, reupload the code and retake measurements.

Following this guide you will have a very robust sensor setup using very high quality probes. These probes are also coupled with a board that has no wire connections with the arduino, offering very high quality readings with very small amounts of noise. Additionally the LCD shield opens up the possibility to add more sensors to your station so that you can monitor, temperature, humidity, and carbon dioxide potentially from a single place.

Comparing the conductivity of two different solutions

Conductivity is perhaps the most misunderstood and erroneously used measurement in hydroponic culture. This has a lot to do

with conductivity also being called a “totally dissolved solid” (TDS) measurement and the conductivity scale being expressed in “ppm” units, concentration units which only cause confusion in this area. Today I want to talk about an important consequence of this confusion that happens when you try to compare the conductivity of different nutrient solutions. I’ll talk about a recent case I encountered and how it generated significant problems due to a natural misunderstanding of how conductivity works.

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A grower wanted to run a side by side trial of two nutrient formulations using identical growing conditions. This grower then decided that the best way to do this was to ensure that the conductivity and pH of the two solutions were identical after preparing the nutrient solutions, then they would both be equivalent in terms of their strength and differences in results would be entirely due to the differences in ionic ratios between both of them. The media was the same, the environment was the same and plant genetics were the same.

However there was a small problem with this thinking. **The same conductivity across two different solutions is not the same thing**. You might think that using a conductivity of 2.0 mS/cm across two different nutrient solutions might mean that their “strength” is the same, but in reality the strength of a solution – as per what a plant really experiences – is determined by its osmotic pressure and osmotic pressure – although proportional to conductivity within the same solution – cannot be extrapolated when the composition of the solution changes. This confusion is further expanded when people see the conductivity numbers in ppm because the expression in mg/L makes them think there is the same “amount of stuff” in the

two solutions. This is not the case.

All the ppm does is tell you that your solution has the same conductivity as a reference with that ppm concentration (commonly NaCl or KCl) but it tells you nothing about how many dissolved solids are really present within your nutrient solution. Given that non-conductive substances also affect the osmotic pressure of a solution it can happen that a nutrient solution with the same conductivity as another one in reality has a lot more dissolved solids, making it far more concentrated in real terms compared to the other one.

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In the above mentioned particular case one solution had a chelating agent that effectively made a significant number of ions neutral in charge (effectively making them non-conductive) reducing the measured conductivity by around 20% at the same osmotic pressure as the other solution. So while the grower was feeding the two solutions at the exact same conductivity, the second solution was around 20% more concentrated in real terms – osmotic pressure terms – compared to the other one. Plants responded very negatively to this – as the conductivity was already quite high – so the grower erroneously assumed that this was due to the ionic ratios instead of it simply being due to an error in judging concentrations. *The second solution was a lot stronger in real terms, although the conductivity was the same.*

When comparing two nutrient solutions you should therefore resort to measurements different than conductivity because the conductivity of two different solutions with different ion compositions cannot be compared, **the same level of conductivity will result in two completely different osmotic**

pressure values. Their strengths will *not* be the same. If you want to compare two different solutions at the same real strength then you need to use an osmometer to determine this point and sadly osmometers are neither cheap nor practical to use.

However another possibility is to simply compare at a constant concentration of a given element. Have a lab analysis of the two fertilizers made – remember you cannot trust labels to give you the real composition values – calculate how much of a given element, for example N, is present at a given application rate and then dial in the other fertilizer to match that N concentration. The osmotic pressures will probably be different but at least under this sort of A/B test you will be comparing apples to apples in the sense that the only variable will be the N:X ionic ratios between the two solutions. Total strengths will differ but this will be due to differences in ionic ratios, which is probably what you want to test.

Controlling aphids in a hydroponic crop. Part 1.

Without a doubt aphids are one of the most common pests affecting crops worldwide. There are both root and leaf aphids, the former which generally live only around plant roots – producing winged offspring only to infest new plants – while the later live generally in plant stems, leaves and – when infestations are bad enough – even within plant flowers and fruits. Today we are going to talk about several

alternatives to deal with aphids, from traditional insecticides to more natural alternatives such as biocontrol options. We are not going to discuss mechanical options here – we'll leave that to part two – as we'll focus only on chemical and biological control within this first part.

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There is one clear winner when controlling aphids. At the present time nothing will beat neonicotinoids in fighting aphids as these insecticides are very effective against a wide range of sucking insects (which are insects that suck material out of plant tissues). Originally made during the mid 1980's and massively popularized during the 1990's (see here) insecticides like imidacloprid have been huge winners in the fight against aphids. They are applied via soil applications – no need for foliar applications – where they are absorbed by the roots and effectively make plant tissue completely toxic for aphids, affecting their nervous system.

However everything is not rosy with insecticides like imidacloprid. Neonicotinoids affect beneficial insect populations – bees in particular (see here) – so they are not good for the environment in general. As a secondary problem they also remain within plants for a really long time so they should only be used when plants are a significant time away from harvest (at least 60 days is usually recommended). When using on edible crops make sure you get a formulation that has been specifically designed for this purpose (like this one). However some legislations require no imidacloprid to be present in plant tissue meant for human consumption so it is important to check with regulatory guidelines regarding its use. There are several studies showing how imidacloprid can accumulate in fruits and flowers (see here for an example in

maize, here for an example in tomatoes).

Perhaps we can resort to less damaging alternatives but still control aphids effectively. Predatory insect applications don't work very well (another post about this coming soon!). But one of the best alternatives I have found so far is to use Lecanicillium Lecanii – and other Lecanicillium species – as a parasitic fungus to attach the aphids. Not only are they effective in attacking aphids but they can also be used as a two-for-one control against powdery mildew and other pathogens as well (see here, here and here). I have had a few recent experiences with customers that have had good success using such fungi to control aphids in several crop types, including parsley and tomatoes. I have had great personal success in parsley, basil and mint plants. These two are the products that I have seen used containing this fungi (here and here). Image below taken from this paper and first image in this post taken from this paper.

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There are also some naturally occurring insecticides that can be used, such as neem oil based products. The problem with these insecticides is that they do work – sort of- depending on the plant and aphid specie you are trying to tackle (see here). Generally 0.2-0.5% emulsions of the oil are effective against aphid populations with such application generally killing most aphids when they work (see here and here). Although neem oil applications shouldn't be considered as a stand-alone solution they can provide a strong head-start when dealing with aphid infestations since they can kill a large portion of the population – if they are susceptible – without harming beneficial insects that might be predating on the aphids already. Last image in this post taken from this paper.

For root aphids the option to use beneficial nematodes also exists. These worms enter the insect bodies and feed on their internal fluids, killing them in the process. However in contrast with fungal spores nematodes do actively seek their pray, so they will hunt the aphids down within the media while a fungal spore needs to meet the aphids randomly. Single nematode species like *Heterorhabditis bacteriophora* can attack aphids although combinations using other nematode species are usually more effective since different nematodes usually attack different species with different efficiencies (see here). Mortality rates when using nematodes are usually at most around 80% so they need to be effectively used in combination with other methods to provide effective control.

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As you can see there are several options for aphid control in your crops. Although using synthetic insecticides like imidiacloprid might be the most effective alternative there are in fact other options that can also be used successfully if the use of a neonicotinoid is not desired. Application of Lecanicillium species has shown to be most effective in peer reviewed studies while nematode and neem applications can help compliment this approach and provide a defense against other insects and pathogens. On the next post in this series we'll talk a bit more about additional aphid control using mechanical means that are neither chemical nor biological.

Five ways to increase your seed germination rates

When you start plants from seeds one of the most important things you want to achieve is a very high and fast germination rate. However if you try to do seed germination without any additional effort you will most likely reach sub-optimal results since there are some natural factors that hinder seed germination that need to be eliminated in order to achieve the best possible results. Today we are going to talk about five things you can do in order to provide the best conditions for the germination of your seeds.

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Temperature is very important. When doing seed germination one of the most critical factors is seed temperature. Some plants require cold temperatures to germinate – for example spinach's germination rate drops to about half when you go from 15 to 25°C – while other plants require higher temperature – for coriander it's basically the opposite. For your seedling emergence rate to be as high as possible ensure that you are giving them the temperature they ideally want, which depends on the plant species. Below you can see a table with germination temperatures for several plant species.

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Pretreat seeds with PEG-6000. Polyethylene glycol treatments can dramatically increase seed germination rates (see here).

We have known this since the mid 1970's and we have also known that the optimum treatment duration and air-drying effects change according to plant species. Applying a general PEG-6000 treatment, as a I described here a few years ago, might or might not work depending on the plant you're trying to work with. For best results you need to search the scientific literature for the best PEG-6000 treatment or – if this information is not present – design your own experiments to figure this out.

Seed disinfection. Seeds are usually covered in microorganisms that can seriously impair seed germination rates. In order to eliminate this issue seeds need to be disinfected prior to germination with a chemical agent (most commonly either hydrogen peroxide or sodium hypochlorite solutions). For this purpose solutions in the order of 0.1-2% NaClO are generally used with different soaking times varying between different papers. You can read more about this sort of process here. Treatments are usually quick with disinfection lasting only a few minutes with subsequent plain water baths to eliminate any excess oxidant.

Introduce some good guys. In the same way that there are pathogens that can hinder seed germination there are some "good guys" that can stimulate seed germination. In particular there are *trichoderma* species that have been known to increase germination rates for some plant species. For example in this paper using okra (see here) there was an important increase in germination rates when using *T. harzianum* as a beneficial fungi. You should look for some scientific literature surrounding the species that interest you or – if that's not available – apply a product that contains a few tr*ichoderma* species.

Using GA_3 for stimulation. The final trick in your arsenal to increase germination rates is to use Gibberellic acid to stimulate your seed germination. Optimum concentration of

gibberelic acid, treatment lengths and effects depend fundamentally on the plant species used but this is acknowledged to be a quite universal stimulant for seed germination rates in the general scientific literature. You can read this paper to see the effects of gibberelic acid on a wide variety of species found in western Australia (so that you can grasp how different its action can be). For particular species you can find articles like this one – for tomatoes – where different GA_3 concentrations are tested to figure out the best application rate. The effect can be quite dramatic as in the image below (taken from this paper).

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In the end there are many things we can do to improve seed germination and the above is by no means an exhaustive list. For particular plant species there can be other tricks – for example things like scarification – which can lead to important improvements in germination rates as well. However the above advice is quite general and can probably help you increase germination rates for a wide variety of plant species.