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***Ocimum basilicum* and *Coriandrum sativum* cultivation in a decoupled anthroponics system**

Henrique Junior Aiveca Sánchez

December 14<sup>th</sup> 2016

Malmö, Sweden

## **Abstract**

Anthroponics is a recirculating soilless agriculture system that uses natural bacterial cycles to convert human biowaste such as urine into plant fertilizer.

A proof-of-concept decoupled system was built in Malmö, Sweden. A deep water culture (DWC) system was built, as well as a moving bed bioreactor (MBBR) with plastic carriers. The MBBR was fed 100-200mL of aged urine collected from one healthy individual, and part of the nitrified liquid was sent to the DWC system containing basil (*Ocimum basilicum*) and coriander (*Coriandrum sativum*) plants. The objective was to test if the separation of the growing component from the bio-filtration component had any effect on the performance of the system in terms of visible nutrient deficiencies and pH levels.

During the first 17 days of the experiment, the plant growth was slow due to diverging pH levels in both components, with pH levels decreasing in the MBBR, and increasing in the DWC. This also affected the plants' leaves, which showed extreme discoloration. After pH correction using phosphoric acid in the DWC and wood ash in the MBBR, plus the addition of chelated iron in the DWC, the plants recovered their color quickly, and growth increased substantially by day 21. After a total of 49 days since the beginning of the experiment, the plants looked healthier than ever, both in the leaves and the roots, though both system components still required weekly pH control.

In conclusion, while this experiment was merely a proof-of-concept, it has shown that a decoupled anthroponics system can work for the production of herbs such as basil and coriander, provided adequate aeration is supplied, and the pH of both the plant growing component and the bio-filter is controlled to optimum levels.

**Keywords:** Anthroponics, basil, coriander, urine, hydroponics, MBBR, wastewater.

## 1. Introduction

Anthroponics can be defined as a recirculating soilless agriculture system that uses natural bacterial cycles to convert human bio-waste such as urine into plant fertilizer. Several past author technical reports describe the main chemical and biological processes such as Ammonia volatilization from urea and the aerobic nitrification of Ammonia to Nitrate (Sanchez<sup>1</sup>, 2015), the different urine dosages (Sanchez<sup>2</sup>, 2015), the use of a catalyst to speed up the ageing process (Sanchez<sup>3</sup>, 2016), and the supplementation of lacking nutrients through the use of wood ash (Sanchez<sup>4</sup>, 2016).

The built proof-of-concept system had the goal to test if separating the growing component from the bio-filtration component by not recirculating them with each other had any effect on the performance of the system, particularly in the pH and nutrient availability. The plants chosen were the herbs basil (*Ocimum basilicum*) and coriander (*Coriandrum sativum*), as they have higher nutrient demands than lettuce, and a faster growth rate than cucumber, the two plants used in previous anthroponics experiments. By separating the two components, it would also be possible to experiment growing plants in an anthroponics deep water culture setup for the first time, with the plants having their roots fully submerged and without any supporting media for the roots.

It was expected that the plants would be able to grow in this system despite the lack of recirculation between the two components, since the process of converting fresh urine to a plant available solution was sequential and that solution had the theoretical amount of macro and micronutrients for the growth of the target herbs.

The results from this proof-of-concept will enable future applications, since the decoupling of the growing component from the bio-filter can enable solutions where, for example, a filter is connected to existing urine diverted infrastructure, and the processed liquid pumped to a nearby anthroponics greenhouse.

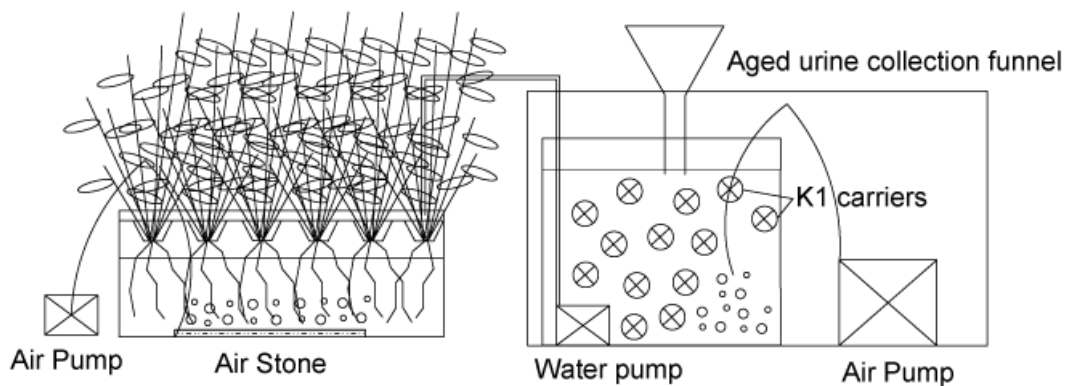
The experiment took place at Hemmaodlat's office. Hemmaodlat is a Swedish Non-governmental organization located in Malmö, Sweden, with the goal of teaching hydroponic and aquaponic concepts, and enabling interested citizens to grow part of their own food at home.

## 2. Materials & Methods

The proof of concept was built out of existing materials at Hemmaodlat's office to reduce cost. An overview of the system can be seen in Figure 1. The deep water culture (DWC) component consisted of a container (approximately 30L) and a lid with 20 holes drilled in, as well as an air pump (HAILEA IPX4 ACO-9601) and an air stone for oxygenation, and net pots in the lid holes for the placement of the herb seedlings. Above the DWC component was an LED light (Växtarmatur Quattro 30W by Venso Ecosolutions) for adequate plant growth, operating during 16 hours per day.

## Deep Water Culture

## Biofilter



**Figure 1:** Proof-of-concept overview

The bio-filter component included a 15L bucket, filled at 50% with carriers from online supplier Dammbutiken (Diameter: 11mm, Height: 7mm, Total surface area: 850 m<sup>2</sup>/m<sup>3</sup>, Protected surface area: 500 m<sup>2</sup>/m<sup>3</sup>) and with a Hailea HX 2500 water pump inside, with three pipes and two 90° connectors, linking the pump to the DWC component. This bio-filter was operated as a moving bed bioreactor (MBBR), with an air pump (HAILEA ACO-9810) supplying air for oxygenation of the liquid for the nitrification process to occur, as well as for the movement of the carriers for good mixing and process rates. The MBBR and the air pump were both inside a bigger IKEA SAMLA box (130L) for easy transportation if needed.

For the maintenance of the system, tap water was added to top-up the DWC and biofilter components, phosphoric acid was used for pH control, wood ash was used for pH control and Potassium and Magnesium supplementation, and Chelated Iron for Iron supplementation. The seedlings were started in ROOT!T® growing medium using General Hydroponics Flora series three part solution.

More detailed information about the systems can be seen in Table 1. The urine was collected from a healthy individual and under no type of medication. The amount of urine used per week was 100-200mL per system, loosely based on the conclusions of a previous report concerning cucumbers (Sanchez<sup>2</sup>, 2015). The urine was stored in a jar containing crushed and dehusked watermelon seeds, and before its addition the urine had its pH monitored to ensure a value greater or equal than 9, rendering it safe for use (Sanchez<sup>3</sup>, 2016).

**Table 1.** Main parameters in the proof-of-concept anthroponic systems.

<b>System</b>	<b>1</b>
<b>Total Water volume (L)</b>	30-45
<b>Pump flow rate (L/h)</b>	-
<b>SSA media (m<sup>2</sup>/m<sup>3</sup>)</b>	500
<b>Biofilter volume (L)</b>	7,5
<b>BSA (m<sup>2</sup>)</b>	3,75
<b>Aged urine (mL/week)</b>	100-200
<b>Experiment duration (days)</b>	50
<b>Plant growing area (m<sup>2</sup>)</b>	0,24
<b>Number of plants in grow box</b>	19
<b>Plant species</b>	<i>Ocimum basilicum</i> & <i>Coriandrum sativum</i>

pH and Electrical Conductivity (EC) were measured with calibrated HM Digital waterproof PH-200 and calibrated HM Digital waterproof COM-100.

To control the pH to an acceptable range of 5,5 – 6,5 (Sommerville *et al*, 2014), a commercial solution containing 59% phosphoric acid (Hesi pH – minus BLOOM commercial solution) was used to lower pH, while wood ash sourced from a private house and achieved by the combustion of birch (*Betula*) and ash tree (*Fraxinus*) wood was used to increase pH and supplement Potassium and Magnesium.

After the carriers in the MBBR were cycled (by the measurement of high nitrate levels) and the system was set-up, it was operated with the following weekly routine:

- Pumping of 100-200 mL from the MBBR to the DWC component;
- Topping-up the DWC and MBBR with tap water until a predetermined level;
- Adding aged urine to the MBBR;
- Measuring EC & pH in the DWC, and pH in the MBBR;
- Adding phosphoric acid and/or chelated Iron to the DWC if needed;
- Adding wood ash to the MBBR if needed.

The thinking behind adding the wood ash in the MBBR instead of the DWC is that, should the pH drop considerably in the MBBR to the point of inhibiting the nitrification process, the wood ash would increase the pH, and in the next week the nutrients originating from the wood ash would also be pumped to the DWC, supplying the plants should they be lacking in Potassium or Magnesium.

### 3. Results

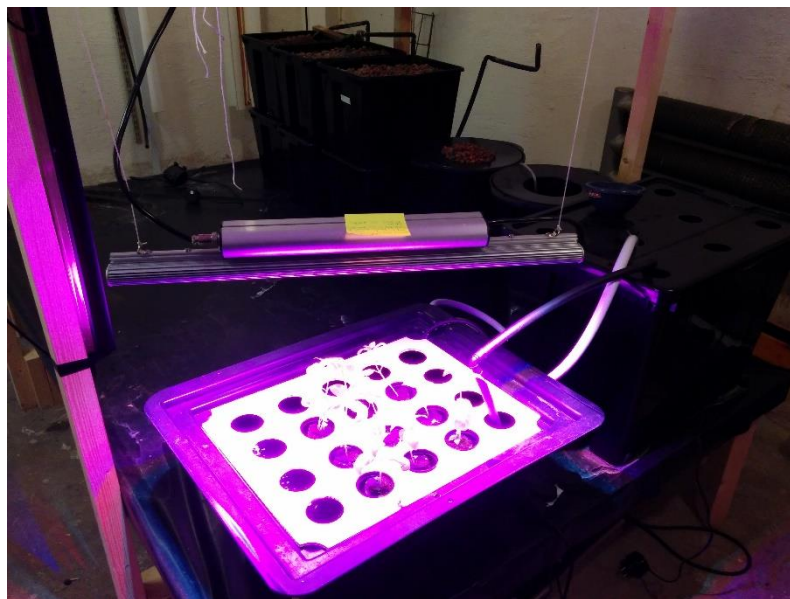
#### 3.1. On site results

The system started with the addition of 6 basil seedlings (Figure 2) on the 19<sup>th</sup> of October 2016, with the addition of 10 coriander seedlings on the 2<sup>nd</sup> of November of 2016.

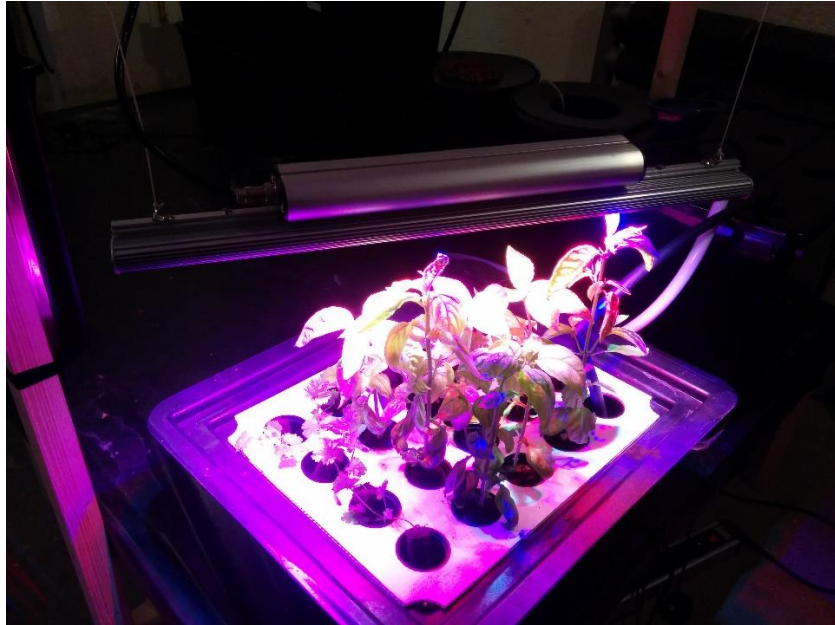


**Figure 2:** Deep water culture component on the (left) and the MBBR on the 26<sup>th</sup> of October 2016.

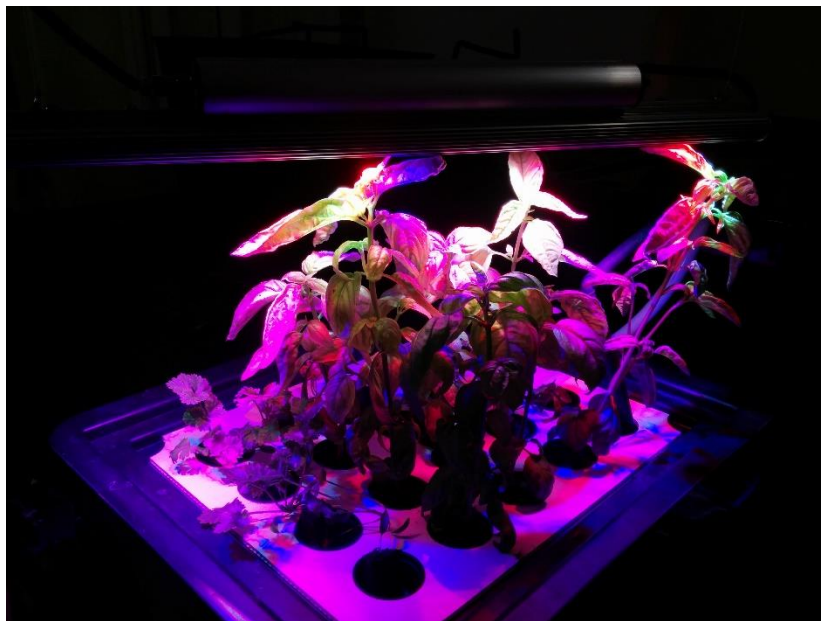
The plants growth was slow at during the first 17 days, while increasing drastically afterwards as a result of pH correction in the MBBR (Figures 3, 4, 5, and 6).



**Figure 3:** Deep water culture component on the 26<sup>th</sup> of October 2016



**Figure 4:** Deep water culture component on the 12<sup>th</sup> of November 2016

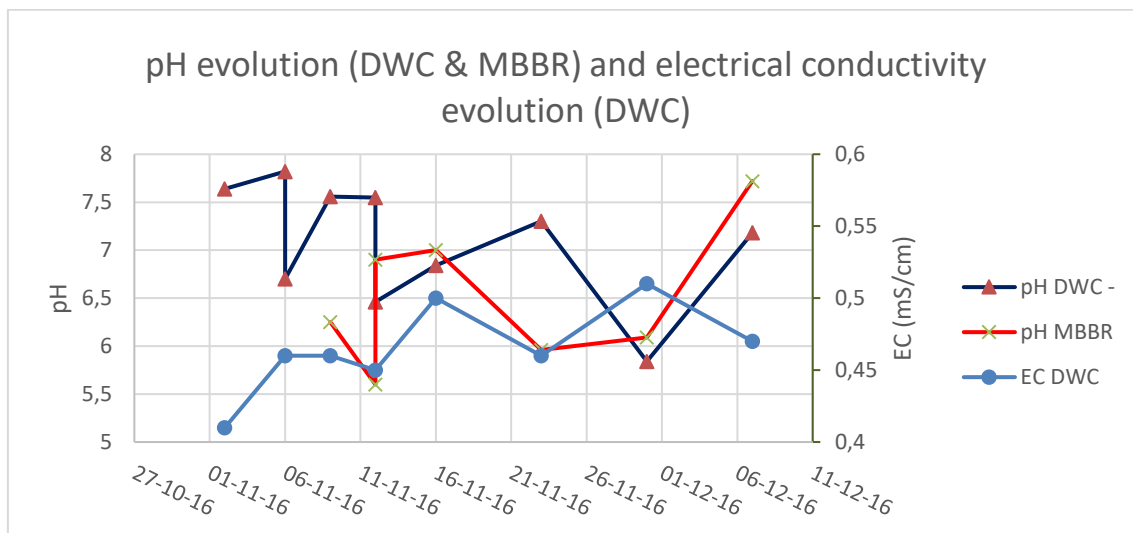


**Figure 5:** Deep water culture component on the 16<sup>th</sup> of November 2016, after the addition of wood ash in the MBBR, and part of the resulting liquid being pumped to the DWC.



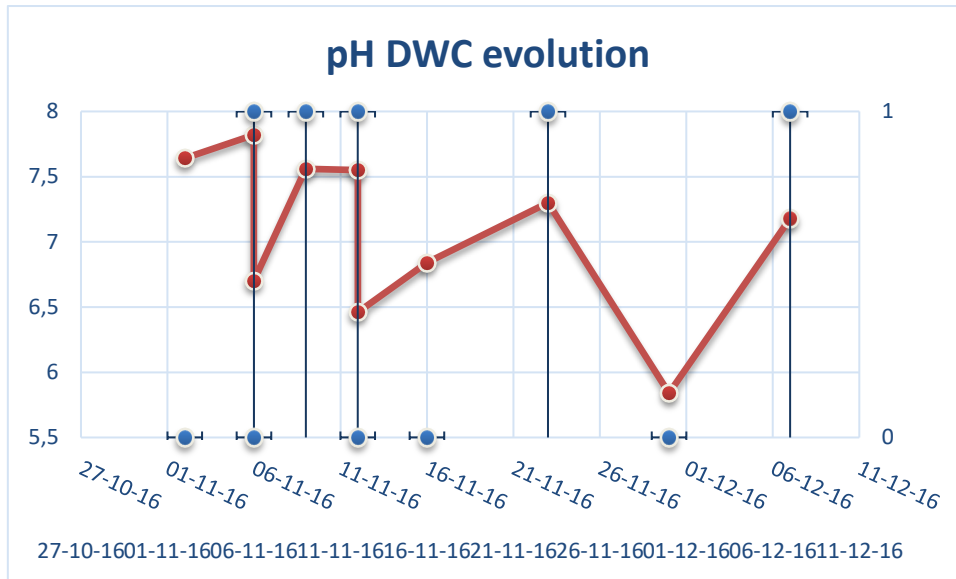
**Figure 6:** Deep water culture component on the 1<sup>st</sup> of December 2016, after the addition of wood ash and chelated iron.

The analysis of pH in the DWC and the MBBR, and the Electrical Conductivity in the DWC (Figure 7), gave some unexpected results regarding the pH, as this diverged considerably as it increased in the DWC while drastically decreasing in the MBBR.



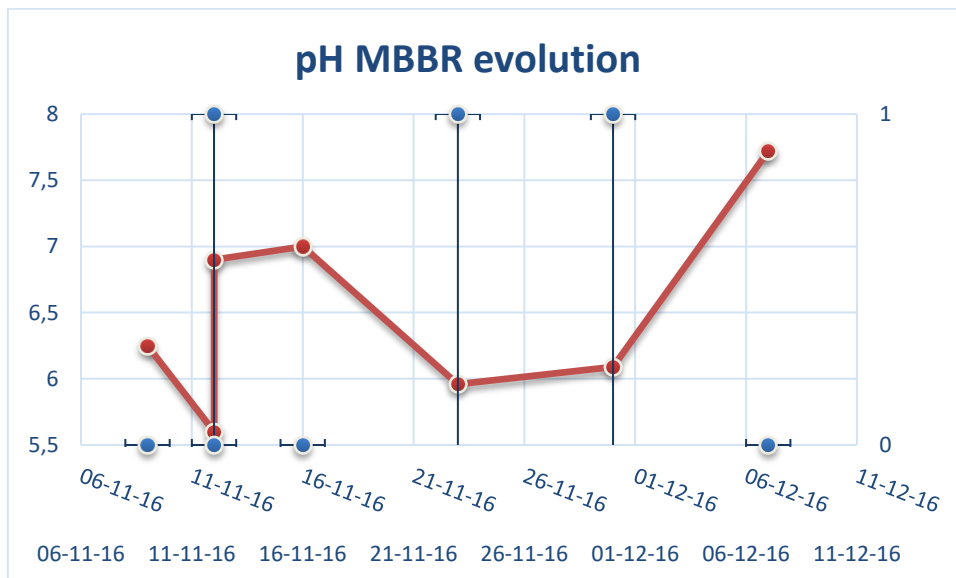
**Figure 7:** Evolution of pH levels over a period of 49 days in the decoupled anthroponics system. Target pH upper limit for the DWC was 7, whereas the target pH lower limit for the MBBR was 6,5.

The increase in pH in the DWC was believed to be the result of the organic compounds released by the plant. This had to be offset with the addition of phosphoric acid, which seemed to help in temporarily lowering the pH (Figure 8).



**Figure 7:** Evolution of pH levels over a period of 49 days in the deep water culture component. The vertical lines indicate when the phosphoric acid was added.

On the other hand, the pH in the MBBR was believed to be a result of the nitrification processes occurring, which tend to draw pH down. It is possible that the pH may have dropped so low at certain times that partial nitrification occurred instead of complete nitrification, which might have affected the plant uptake when part of its water was sent to the DWC component. The addition of wood ash seemed to temporarily increase the pH to offset this decrease (Figure 8).



**Figure 8:** Evolution of pH levels over a period of 49 days in the moving bed bioreactor component. The vertical lines indicate when wood ash was added.

Some nutrient deficiency signs were observed during the experiment (Figure 8), particularly in the basil plants. These signs included severe discoloration in old and new leaves.



**Figure 9:** Close-up on basil plants in the DWC showing strong deficiency signs. 12<sup>th</sup> November 2016.

## 4. Discussion and conclusions

### 4.1. pH

During the whole experiment it was necessary to control the pH in both components. In the MBBR, there was a tendency for the pH to decrease as the nitrification process occurred. In the DWC there was a tendency for pH to increase possibly due exudates released by plants. The addition of phosphoric acid in the MBBR, and of wood ash in the DWC seemed to have the intended effect of reducing and increasing the pH, respectively.

It is likely that the lower pH in MBBR affected not only the availability of Ammonia, but also the nitrification process. Nitrification is done by Ammonia oxidizing bacteria (such as *Nitrosomonas*) and by Nitrate oxidizing bacteria (such as *Nitrobacter* and *Nitrospira*). *Nitrosomonas* have an optimum pH range of 6.0 – 9.0 (JGI, 2016), and their growth becomes inhibited at a pH below 6.0 (Fumasoli *et al*, 2015). *Nitrobacter* have an optimum development at a pH range of 7.6 – 8,2 (Grunditz & Dalhammar, 2001) with a lower limit at a pH of 6.5 (Boon & Laudelout, 1962). *Nitrospira* have an optimum pH range of 8.0 – 8.3 (Blackburne *et al*, 2007). On several occasions the pH level dropped considerably below 6.0, which would inhibit *Nitrosomonas*. The lower pH levels in the MBBR may have, at times, completely inhibited the nitrification process, or at least, partially inhibited the process. This could lead to higher Ammonia and Nitrite levels than expected, which may have been transferred to the DWC at some time, also negatively affecting the plant.

On the other hand, the higher pH level in the DWC likely affected the herbs' development. It is known that basil prefers a pH level between 5,5 – 6,5 (Sommerville *et al*, 2014), and that nutrient availability changes with differences in the surrounding pH (Figure 10).

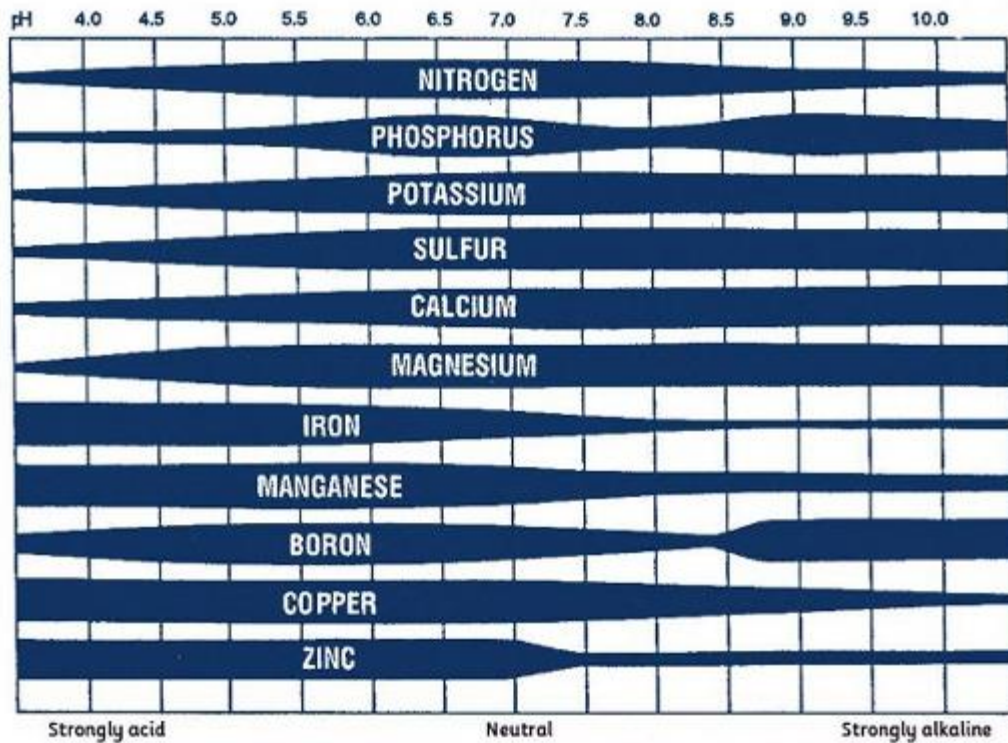


Figure 10: Effect of pH on nutrient uptake in soil. Silveira, 2013.

#### 4.2. Electrical conductivity

Electrical conductivity was relatively stable throughout the experiment, with a slight increase after the addition of wood ash and chelated iron in the DWC. Since electrical current is transported by the ions in solution, the conductivity increases as the concentration of ions increases. In this case, a greater amount of ions was present after the addition of wood ash and chelated iron. It is also possible that there was a slight tendency for electrical conductivity to increase over time given that a higher pH might have affected nutrient uptake by the plant, and therefore the amount of ions present in the water.

#### 4.3. Conclusions

In conclusion, while this experiment was merely a proof-of-concept, it has shown that a decoupled anthroponics system can work for the production of herbs such as basil and coriander, provided adequate aeration is supplied, and the pH of both the plant growing component and the bio-filter is controlled to optimum levels.

Future experiments should attempt to optimize the growing process by adding the wood ash and the chelated iron from the start of the experiment, to check if the deficiencies still emerge in the plant tissue. This addition of wood ash, however, should be just enough so as to not inhibit the nitrifying bacteria with a too high pH. Future experiments should also incorporate a wider collection of urine from other healthy individuals, and the set-up of a trial where a filter is connected to existing urine diverting systems, connecting the filter effluent to an anthroponic greenhouse.

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