

# Nutrient Management in Aquaponics *at Auburn* *University*

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- Aquaponics – Aquaculture + Hydroponics
- Basic idea is:
  - Multiple uses of water
  - Recover as much **value** from inputs as possible
  - **Minimize** negative environmental impact
  - Sustainable system

# What are we growing?

- What are you growing in an aquaponic system?
- *At least 3 things:*
  1. Aquatic animals (usually fish)
  2. Plants (high value)
  3. Bacteria

# Plants

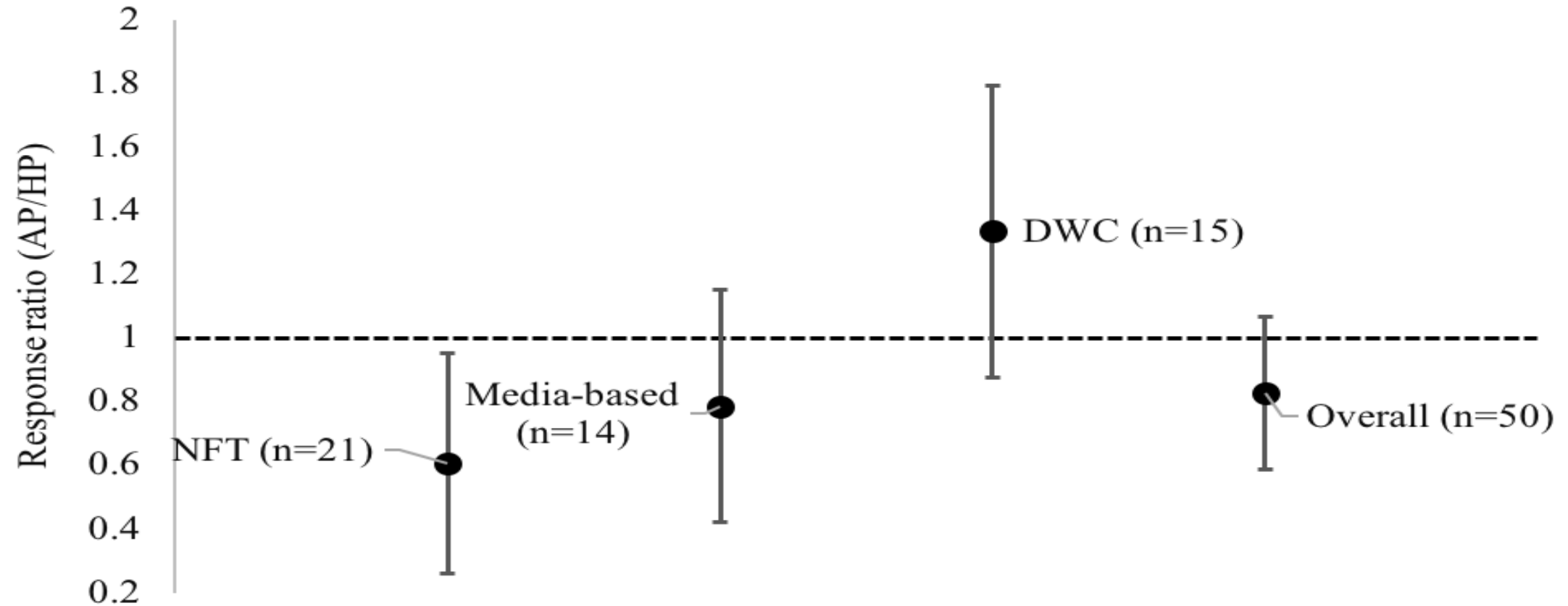
- Need to grow high-value plants.
- Species that are **normally grown in hydroponics.**
- With some exceptions possibly...

# Choosing a Hydroponic System

- Several, proven technologies
- Based on the type of plant(s) you want to grow and how you want to manage them
- Two basic categories that we can use:
  1. **Water Culture**
  2. **Soilless Substrate Culture**

# Hydroponic System

How is plant yield affected by system type?



## **NFT:**

Nutrient  
Film  
Technique

- Recirculating system
- Not typically aerated
- Easy to use for growers



## DWC:

Deep Water Culture or Raft Culture

- Recirculating or static system
- Typically aerated
- Inexpensive option
- More laborious than NFT



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# Dutch Bucket Culture



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## Rockwool Culture



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**Rockwool Culture**



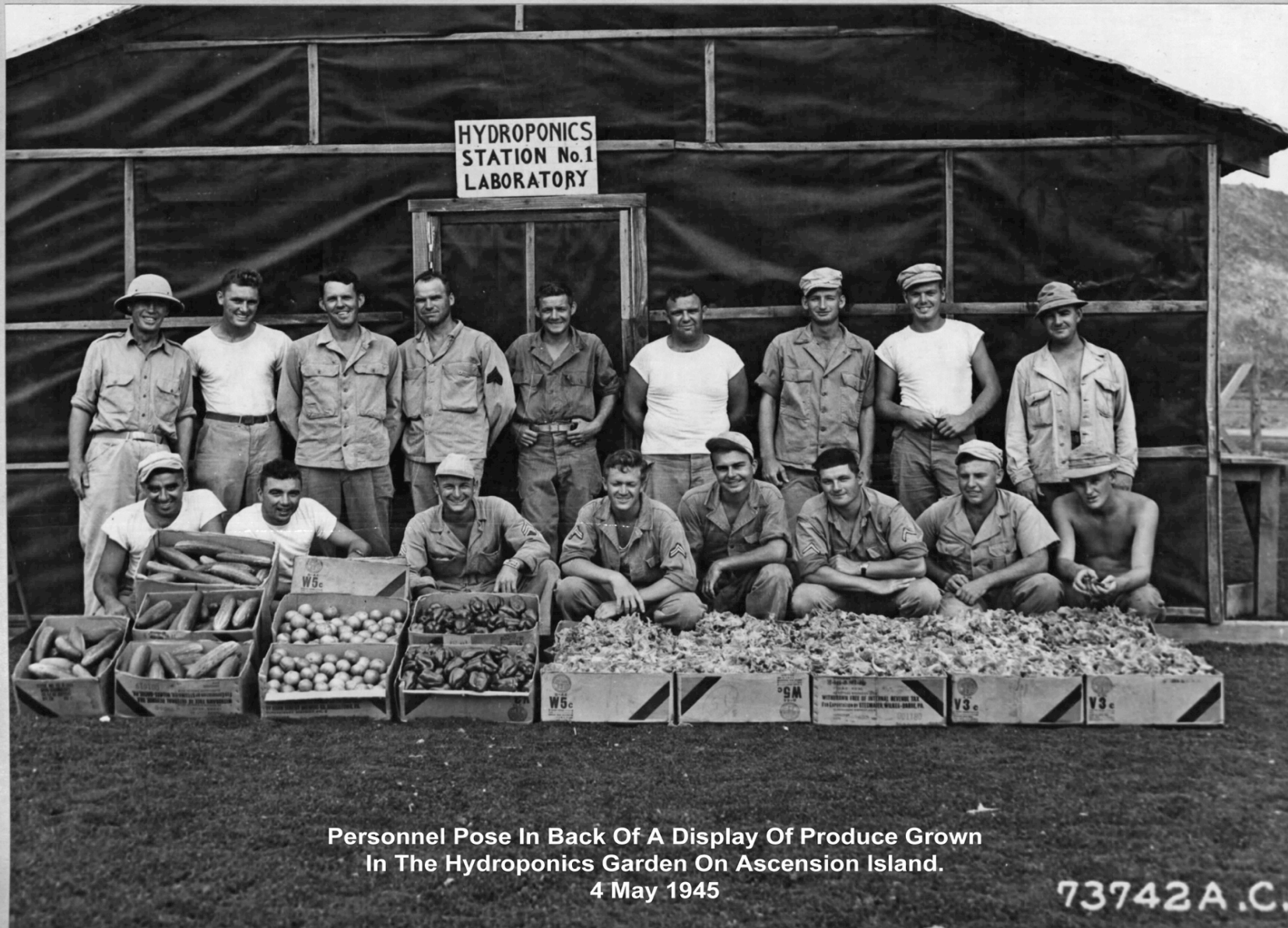
Coconut Coir Culture

# Indoor/Vertical Farming



War Theatre #7 (Ascension Island)  
FIELDS & INSTALLATIONS

Orig. 4x5 neg rec'd 26 March 1946 from Com-  
posite Force 8012, APO #877, c/o P.M., Miami,  
(over) Florida.



Hydroponics

4588

Personnel Pose In Back Of A Display Of Produce Grown  
In The Hydroponics Garden On Ascension Island.  
4 May 1945

73742A.C.

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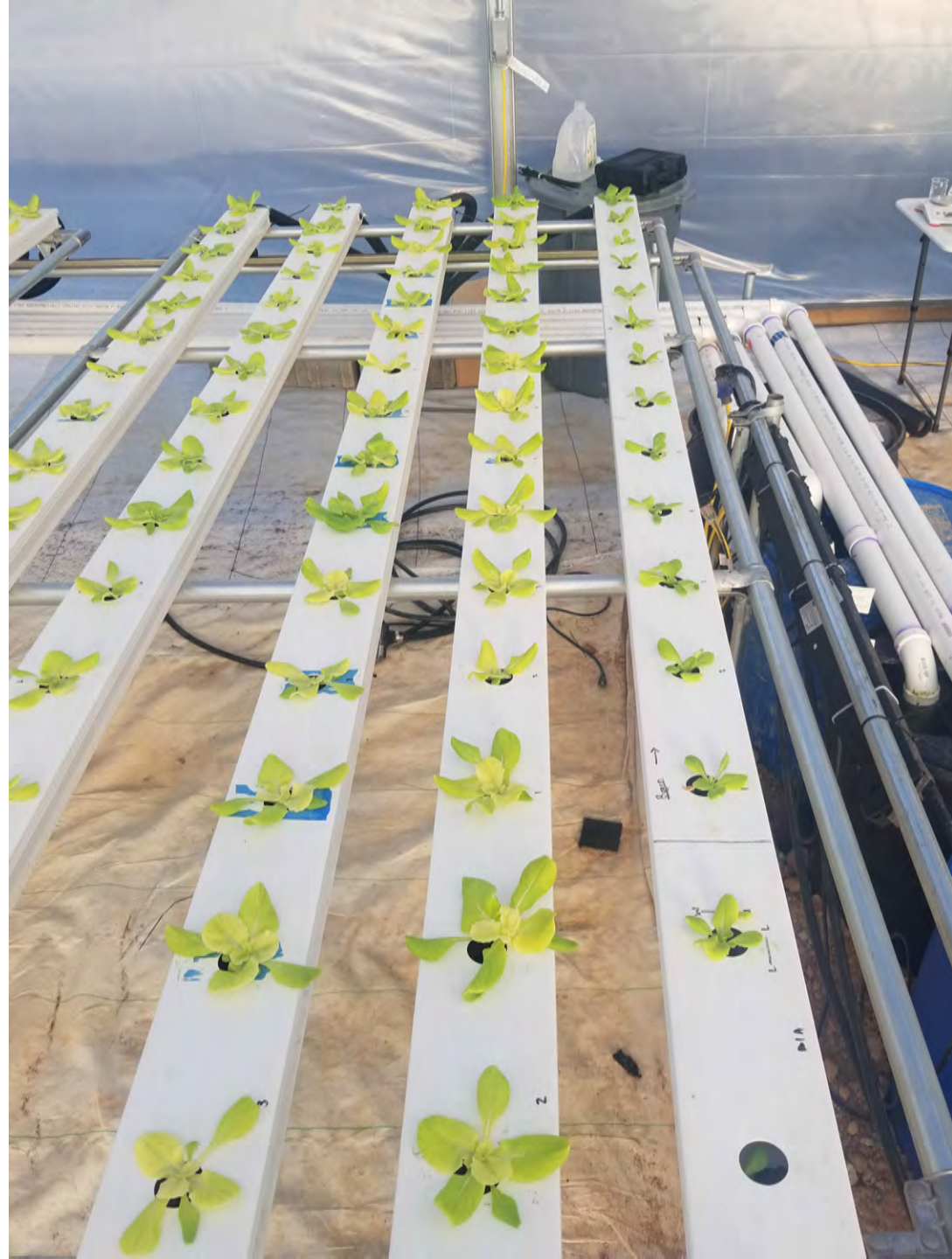
# Plant Nutrition and Common Problems in Aquaponics

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# What are plant nutrients?

- Essential elements required for normal plant growth.
- Present in soil solution or nutrient solution.
- All essential elements **MUST** be provided by the grower in an aquaponic system.

# What is a plant made of?

- 80 – 90% water ( $\text{H}_2\text{O}$ )
- 10 – 20% dry matter
- 96% of dry matter is Carbon (C), Oxygen (O), and Hydrogen (H)
- 99.2 – 99.6% of the entire plant = C, O, H
- ***0.4 – 0.8% other elements***

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- 10 – 20% dry matter
- 96% of dry matter is Carbon (C), Oxygen (O), and Hydrogen (H)
- 99.2 – 99.6% of the entire plant = C, O, H
- ***May be as high as 1 – 2% other elements***

# Three Rules for Essentiality

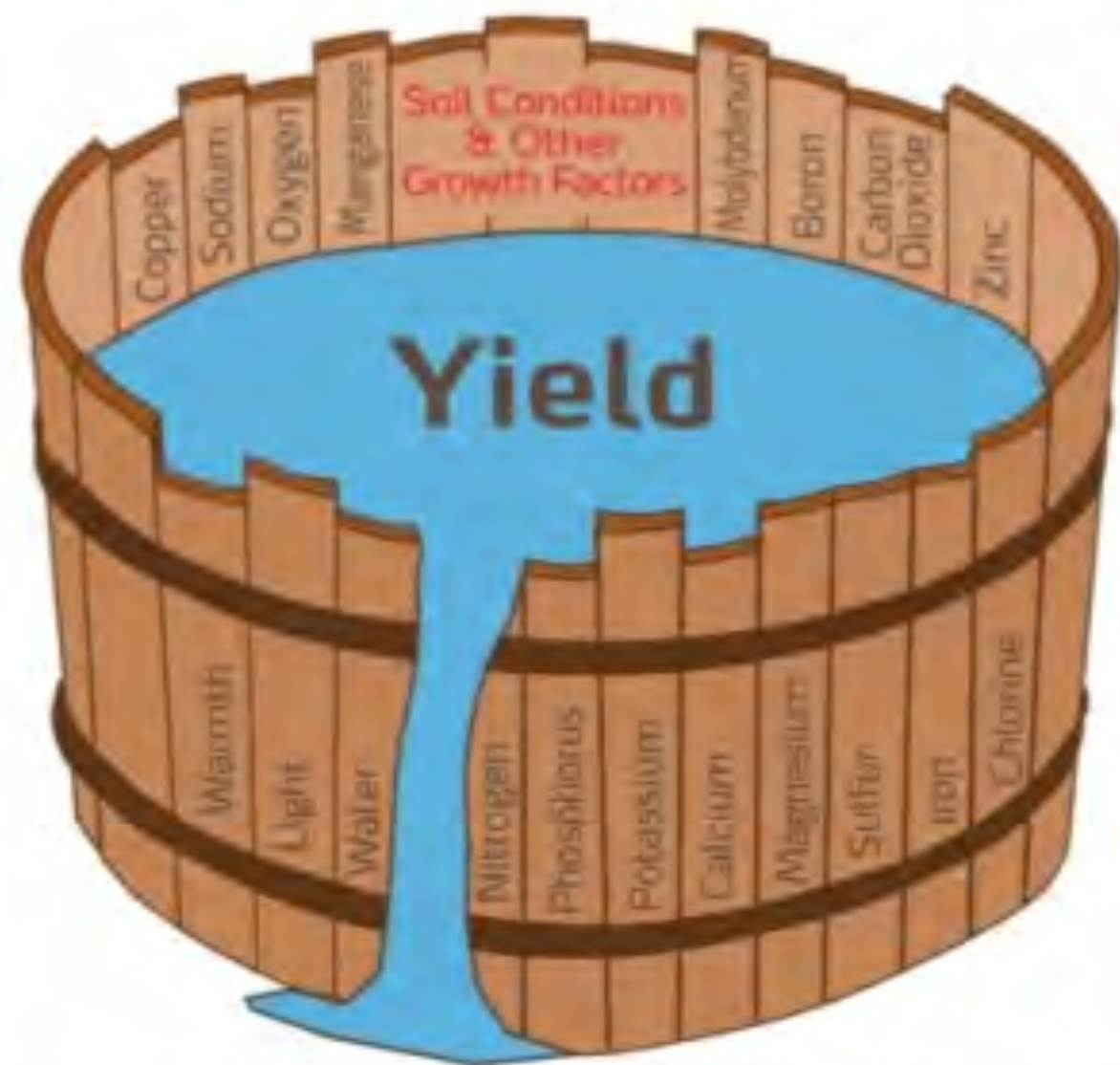
1. The element must be needed by the plant to complete its life cycle.
2. No other element can substitute for the element in question.
3. The element must exert its effect directly on growth or metabolism and not by some indirect effect.

# Law of the Minimum

- Liebig's "*law of the minimum*" states that yield is proportional to the amount of the **most limiting** nutrient, **whichever** nutrient that may be.
- Plant growth and yield **can and will** be limited by the the absence or limiting quantity of **any** of the essential elements.

**Justus von Liebig's  
"Law of the Minimum"  
published in 1873**

"If one growth factor/nutrient is deficient, plant growth is limited, even if all other vital factors/nutrients are adequate...plant growth is improved by increasing the supply of the deficient factor/nutrient"



JUSTUS VON LIEBIG 1803 - 1873

# 18 Essential Elements

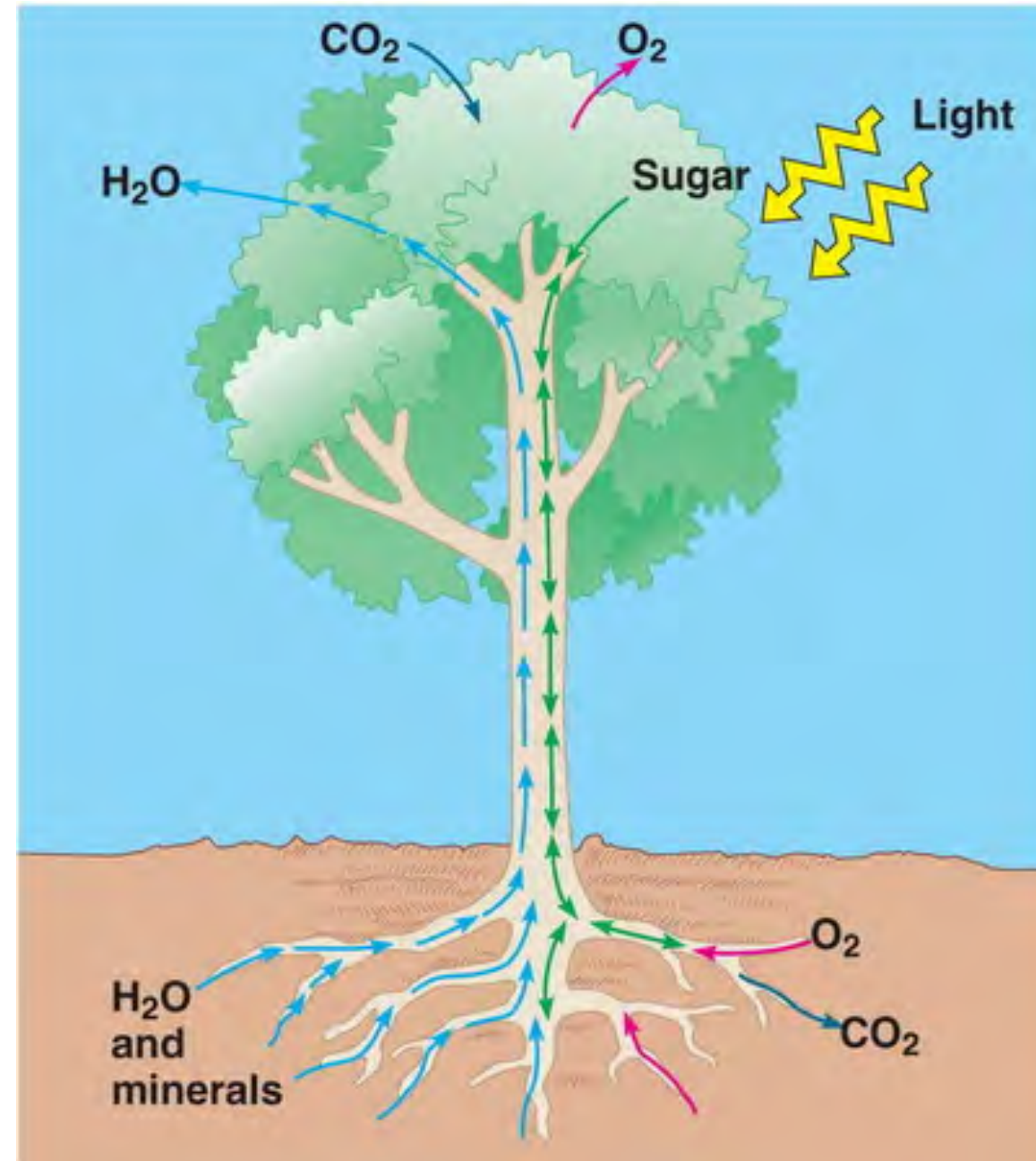
- C, O, H, N, P, K, Ca, Mg, S, Cl, Fe, Mn, B, Zn, Cu, Mo, Ni, Al
- Typically divided into macro- and micronutrients.
- Depending on source, between 14 and 18 essential elements.

# The Nutrient Solution

- Essential elements ***must be*** dissolved in water and in the ***proper form*** to be plant-available.
- In soil – elements are dissolved in the soil solution before being “taken up” by plant roots.
- Root hairs come into contact with soil solution and elements can pass into the plant.
- Electrochemical gradients

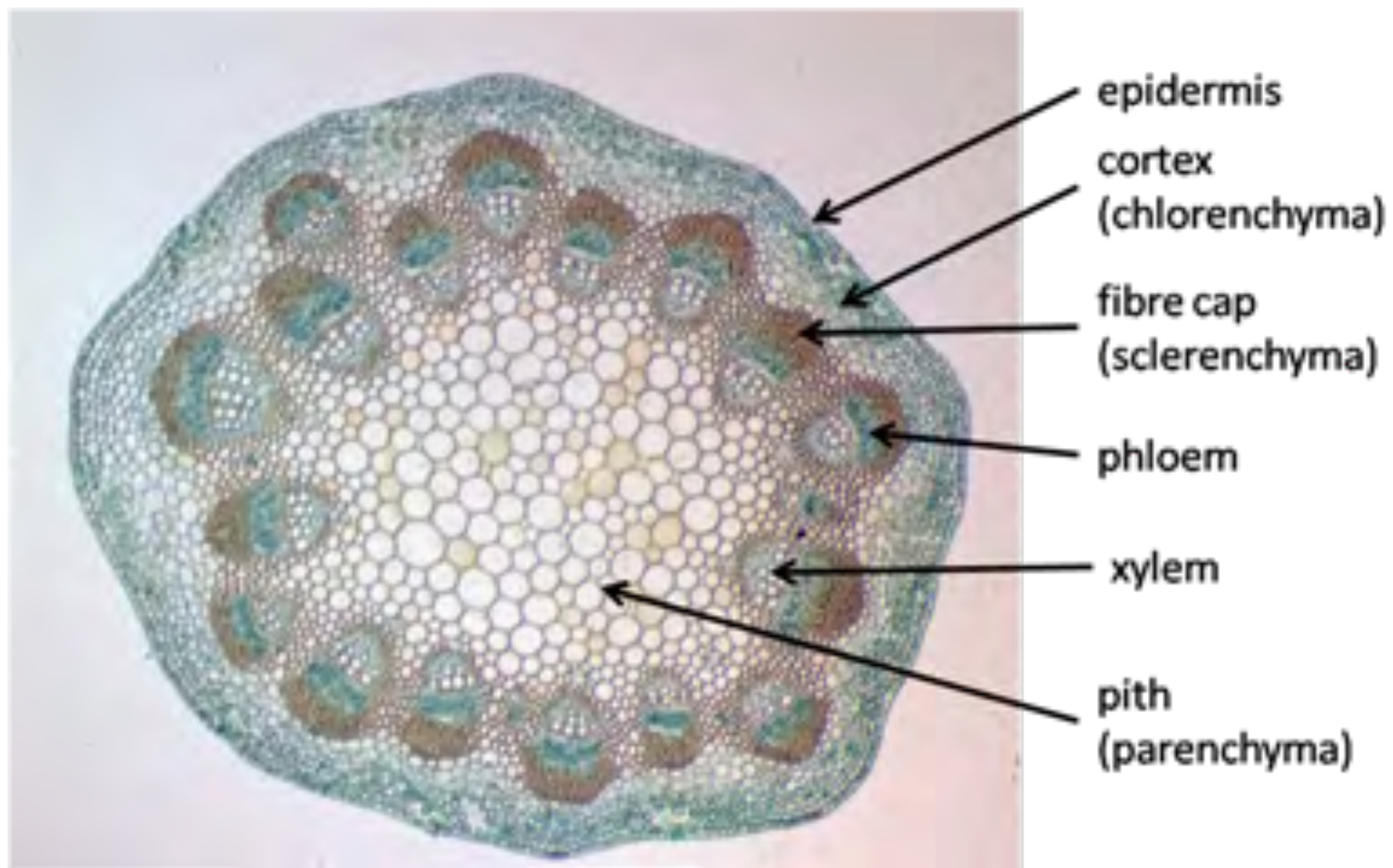
# Transpiration and Mass Flow

- Essentially, in a hydroponic system mass flow is the method of all nutrient movement to plant roots.
- Driven by transpiration.



# Xylem

- The xylem is a “one way street”.
- “Zip ***up***” the xylem.
- The other conductive tissue in the plant is called the **phloem**.
- Photosynthates (sugars) are transported from leaves to others parts of the plant via the phloem.

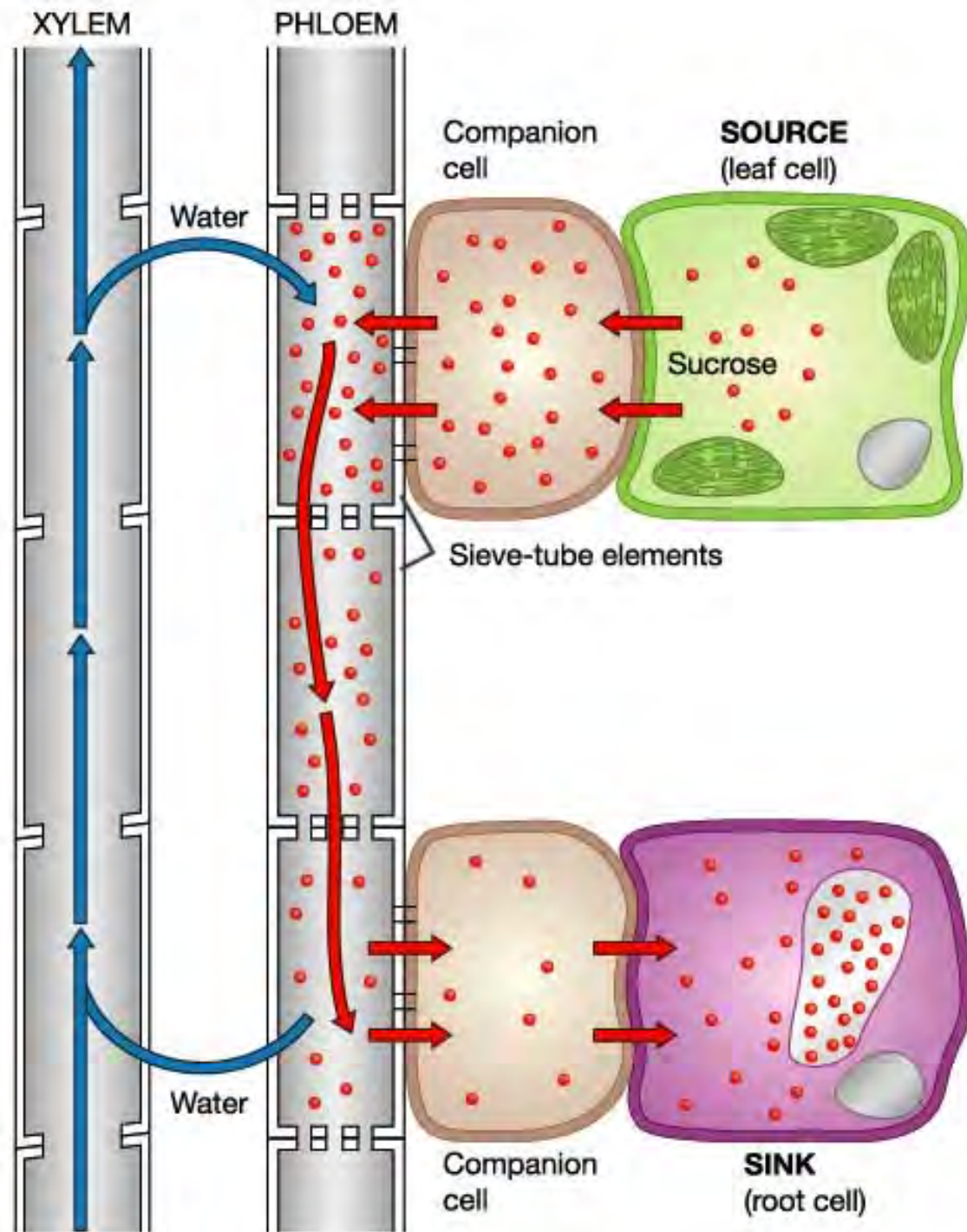


# Phloem

- Not only transports sugars, but also nutrients (if needed).
- Important concept in plant nutrition.
- “Flow ***down*** the phloem”
- Phloem transport can lead to clues about nutrient deficiencies.

# Nutrient Mobility

- Elements are generally (relatively) mobile or immobile within plants.
- Phloem transport – **retranslocation**



# Mobile or Immobile?

- By asking a basic question we can determine what category the deficient nutrient fits into.
- Where did symptoms first appear?
- A: New growth – **Immobile nutrients**
- A: Old growth – **Mobile nutrients**

# Mobility within Plants

## Mobile Nutrients

- N
- P
- K
- Mg
- Zn
- Mo
- Cl

## Immobile Nutrients

- Ca
- Fe
- B
- S
- Cu
- Mn



# Problems in the AU Aquaponics System

## Mobile Nutrients

- N
- P
- K
- Mg
- Zn
- Mo
- Cl

## Immobile Nutrients

- Ca
- Fe
- B
- S
- Cu
- Mn



# Nutrient Deficiencies

Concepts, Causes, and Symptoms



# Nutritional Disorders

- Deficiency or excess of an essential element can cause a malfunction in plant physiology.
- Often accompanied by visual symptoms.
- Symptoms can be different between plant species.

# Nutrient Management



Ensure proper concentrations /  
availability / ratios



pH management



Environmental conditions  
(temperature, photoperiod, RH)

# Ensure availability

Element not present in adequate quantities

- It's important to know what is in solution at all times. Know what we start with..
- If adequate concentrations are not available, we simply can add more of that nutrient (sometimes not so simply)

# Ensure availability

Other elements antagonize uptake

- Nutrient is present in solution.
- Bound/sorbed/precipitated with other element(s).
- Out-competed by other elements for entry into plant cells

## Solution pH

- Elements are present, but in the wrong form.
- pH often dictates form.
- *Sorption / precipitation reactions (Ca – P)*

# What is pH?

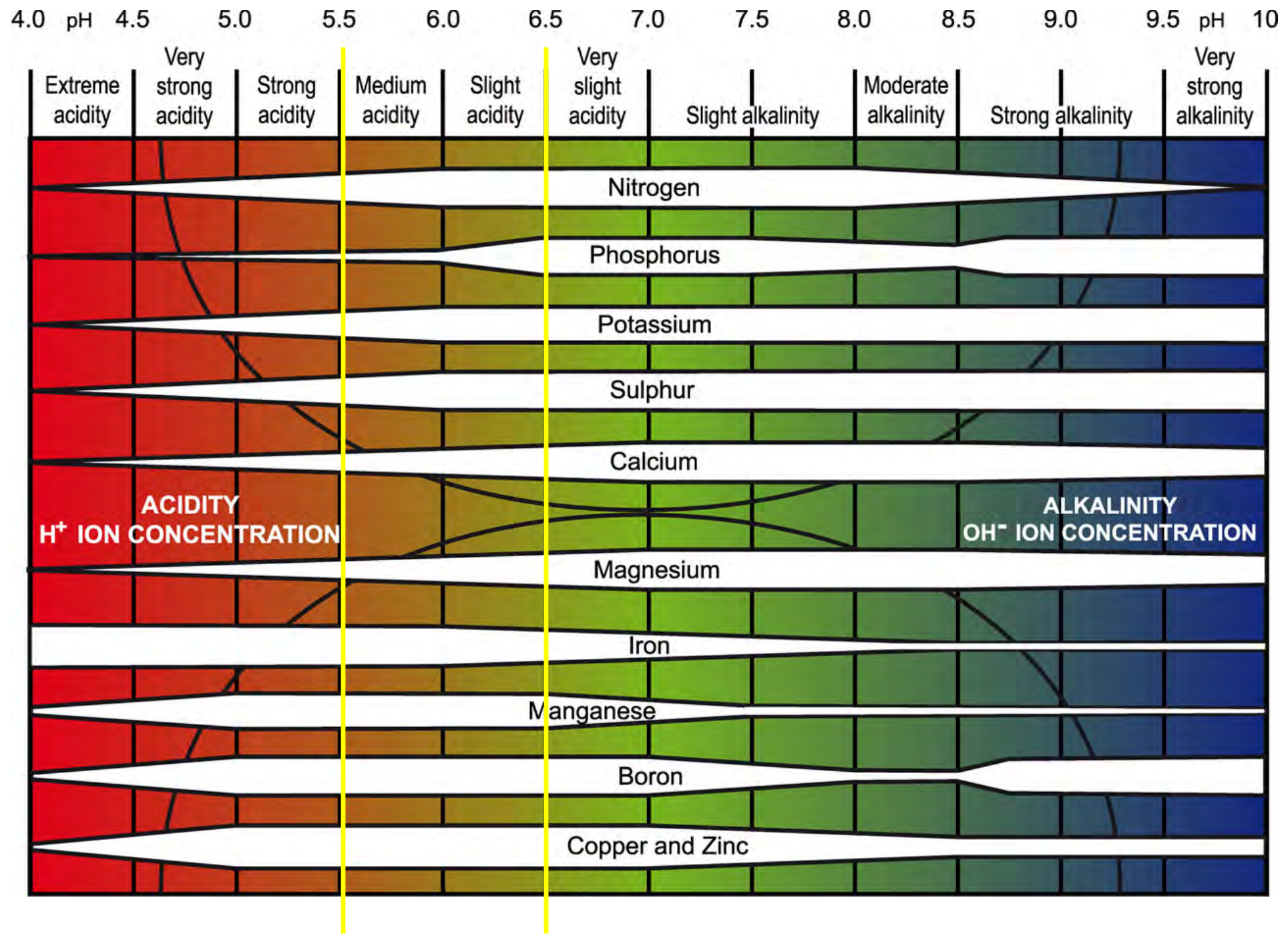
- pH is the concentration of  $H^+$  in soil solution or nutrient solution (or any other solution)
- Measured on a logarithmic scale from 0-14.
- Logarithmic means every whole number change in value equals a 10x concentration change of  $H^+$ .
- Measurable change in pH is a big deal!

# pH: The Chemical Driver

- pH needs to be reconciled for at least three types of species (fish, bacteria, plants)
- One of the possible difficulties with aquaponics
- Coupled vs. Decoupled
- At AU we have a de-coupled system

# Proper pH Management

- The approach in hydroponics:
- Ensure pH remains constant.
- Usually pH = **5.8**



# pH Experiment for Cucumber production

- Designed an experiment to keep pH high in fish system and lower for plant system.

Target pH treatments

1. 7.0 (control)
2. 6.5
3. 5.8
4. 5.0

Acids used:

Citric Acid

Sulfuric Acid

Injected using  
Chemilizer  
Injectors



# NITRIFICATION

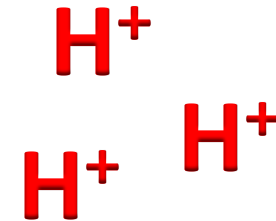
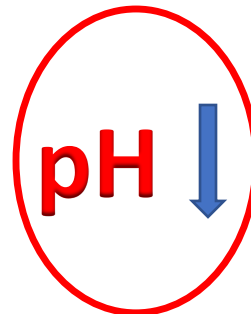
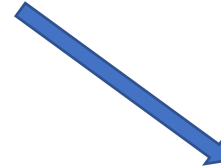
Ammonia ( $\text{NH}_3$ ): Ammonium ( $\text{NH}_4^+$ )  
TAN



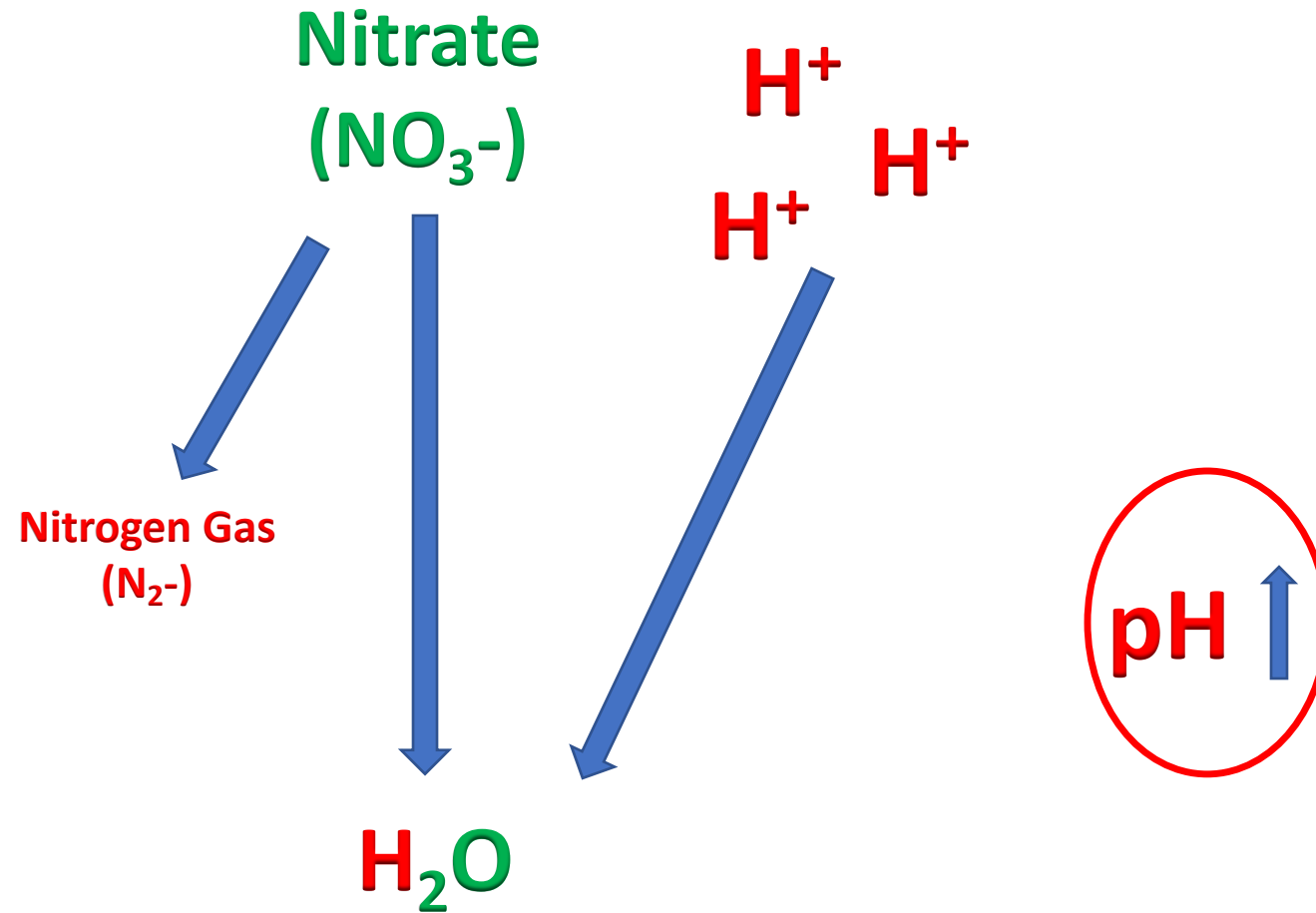
Nitrite  
( $\text{NO}_2^-$ )



Nitrate  
( $\text{NO}_3^-$ )



# DENITRIFICATION



	AU Aquaponics Water	Recommendations Hydroponic Cucumbers	Foliar Sufficiency Ranges for Greenhouse Cucumber	pH = 7.0	pH = 6.5	pH = 5.8	pH = 5.0
N	180	135	4.5-6.0%	5.7%	5.6%	5.8%	5.7%
P	7.5	62	0.34-1.25%	0.62%	0.51%	0.54%	0.51%
K	100	150	3.90-5.00%	3.2%	3.4%	3.2%	3.3%
Ca	185	130	1.4-3.5%	4.6%	4.7%	4.9%	4.5%
Mg	20	50	0.3-1.0%	0.46%	0.51%	0.51%	0.46%
S	50	70	0.4-0.7%	0.98%	0.9%	1.1%	1.0%
Fe	0.05	2.5	50-300 ppm	78 ppm	89 ppm	86 ppm	144 ppm
B	0.08	0.4	25-60 ppm	43 ppm	38 ppm	40 ppm	38 ppm
Cu	0.02	0.05	7-20 ppm	11 ppm	9 ppm	10 ppm	10 ppm
Mn	0.05	0.6	50-300 ppm	184 ppm	118 ppm	166 ppm	214 ppm
Zn	0.1	0.1	25-100 ppm	79 ppm	61 ppm	62 ppm	79 ppm



Target pH = 5.8

Yield = 20 kg / m<sup>2</sup>



Target pH = 7.0

Yield = 19.4 kg / m<sup>2</sup>

# Ensure Proper Concentrations

- The approach in hydroponics:
- Ensure all nutrients are in high enough concentrations that none are limiting.
- Balance nutrients / Ensure proper ratios

Nutrient  
Concentrations  
for Greenhouse  
Vegetables in  
ppm (final  
solution)

	Tomato	Cucumber	Lettuce	AU Aquaponics
N	105	135	200	180
P	60	62	62	7.5
K	200	150	150	100
Ca	100	130	210	185
Mg	50	50	40	20
S	70	70	70	50
Fe	2.5	2.5	2.5	0.05
B	0.4	0.4	0.4	0.08
Cu	0.05	0.05	0.05	0.02
Mn	0.6	0.6	0.6	0.05
Zn	0.1	0.1	0.1	0.1

Nutrient Concentrations for Greenhouse Vegetables in ppm  
(final solution)

	Tomato	Cucumber	Lettuce	AU Aquaponics
N	105	135	200	180
P	60	62	62	7.5
K	200	150	150	100
Ca	100	130	210	185
Mg	50	50	40	20
S	70	70	70	50
Fe	2.5	2.5	2.5	0.05
B	0.4	0.4	0.4	0.08
Cu	0.05	0.05	0.05	0.02
Mn	0.6	0.6	0.6	0.05
Zn	0.1	0.1	0.1	0.1

# Hydraulic retention time study for NFT

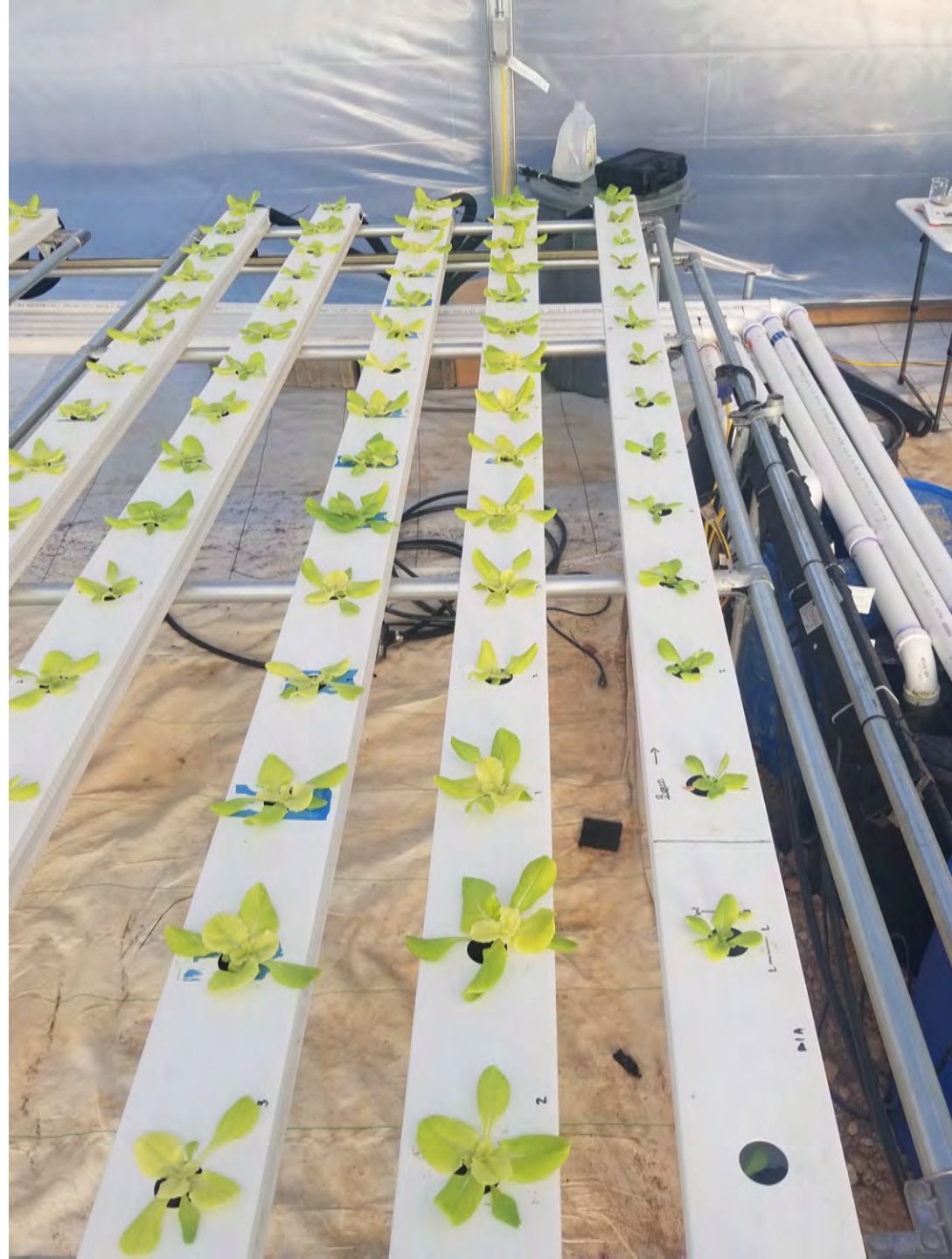
- Designed an experiment to exchange water at different intervals to determine effects of cumulative nutrient loads.

## Treatments

1. Hydro control (16 day)
2. 16 day
3. 12 day
4. 8 day
5. 4 day

**\*\*Screened effluent to remove most solids**

**\*\*No nutrient supplementation**



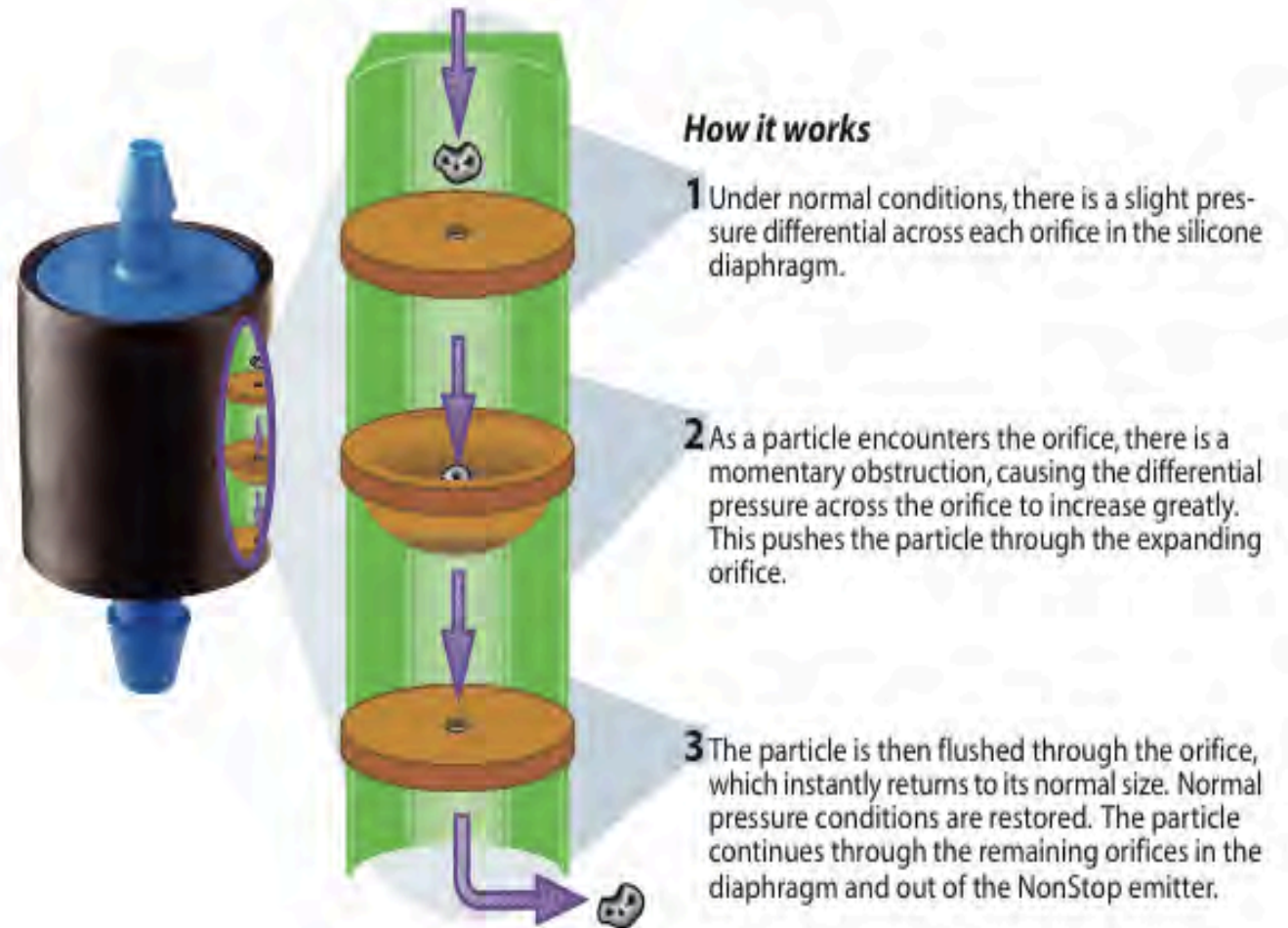
	AU Aquaponics Water	Foliar Sufficiency Ranges for Greenhouse Lettuce	4 Day	8 Day	12 Day	16 Day	Hydro
N	180	4.5-6.5%	5.4%	5.6%	5.9%	6.0%	5.9%
P	7.5	0.3-0.8%	0.58%	0.63%	0.63%	0.60%	0.60%
K	100	6.0-10%	7.8%	8.5%	8.6%	8.9%	7.7%
Ca	185	1.0-2.0%	3.7%	3.3%	3.4%	3.4%	2.0%
Mg	20	0.35-0.75%	0.48%	0.47%	0.50%	0.51%	0.52%
S	50	0.2-0.6%	0.3%	0.3%	0.3%	0.3%	0.3%
Fe	0.05	50-200 ppm	87 ppm	78 ppm	83 ppm	60 ppm	132 ppm
B	0.08	25-80 ppm	23 ppm	26 ppm	29 ppm	34 ppm	71 ppm
Cu	0.02	5-15 ppm	7 ppm	7 ppm	7 ppm	6.8 ppm	6.4 ppm
Mn	0.05	20-200 ppm	692 ppm	781 ppm	591 ppm	399 ppm	315 ppm
Zn	0.1	20-75 ppm	273 ppm	244 ppm	227 ppm	172 ppm	65 ppm

	AU Aquaponics Water	Foliar Sufficiency Ranges for Greenhouse Lettuce	4 Day	8 Day	12 Day	16 Day	Hydro
N	180	4.5-6.5%	5.4%	5.6%	5.9%	6.0%	5.9%
P	7.5	0.3-0.8%	0.58%	0.63%	0.63%	0.60%	0.60%
K	100	6.0-10%	7.8%	8.5%	8.6%	8.9%	7.7%
Ca	185	1.0-2.0%	3.7%	3.3%	3.4%	3.4%	2.0%
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# How is this possible?

- NFT Lettuce
- **Removed most solids**
- Avoid clogging the system
- Dutch Bucket Cucumbers
- **Solids deposited with irrigation**
- Clog-free emitters (Bowsmith)



# Solids may be the key for micronutrients in substrate culture...

- **Most iron (Fe) and boron (B) are bound/sorbed to solid waste**
- Very scarce in solution
- Substrate allows for interaction between solids and plant roots
- Bacterial siderophores are a possible mechanism
- **Rhizosphere microbiome research needed**





Tipburn – Calcium deficiency

**NOT usually caused by lack of Ca in solution**

Caused by high humidity

Made worse by high temperatures / long photoperiods

## Dealing with calcium deficiencies

- Almost always an environmental problem
- Increase air movement (vertical for lettuce)
- Reduce EC if possible
- Try to slow growth (chill solution?)

# Hydroponic System

How is plant yield affected by system type?

