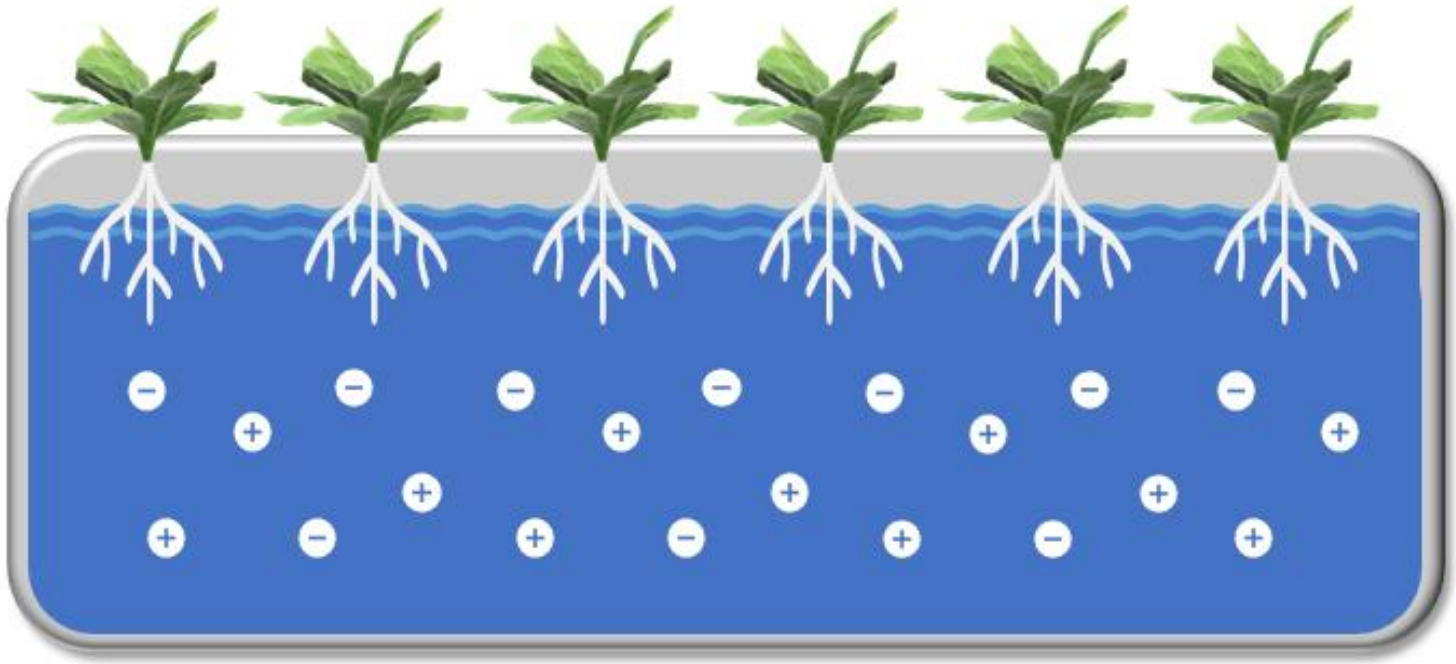

Module 3
Hydroponic Nutrient Solutions

2026 Greenhouse Hydroponic Tomato Workshop with Dr. Triston Hooks

Outline

1. EC and pH
2. Nutrient Solution Recipes
3. Concentrated Stocks
4. Fertigation for Tomatoes

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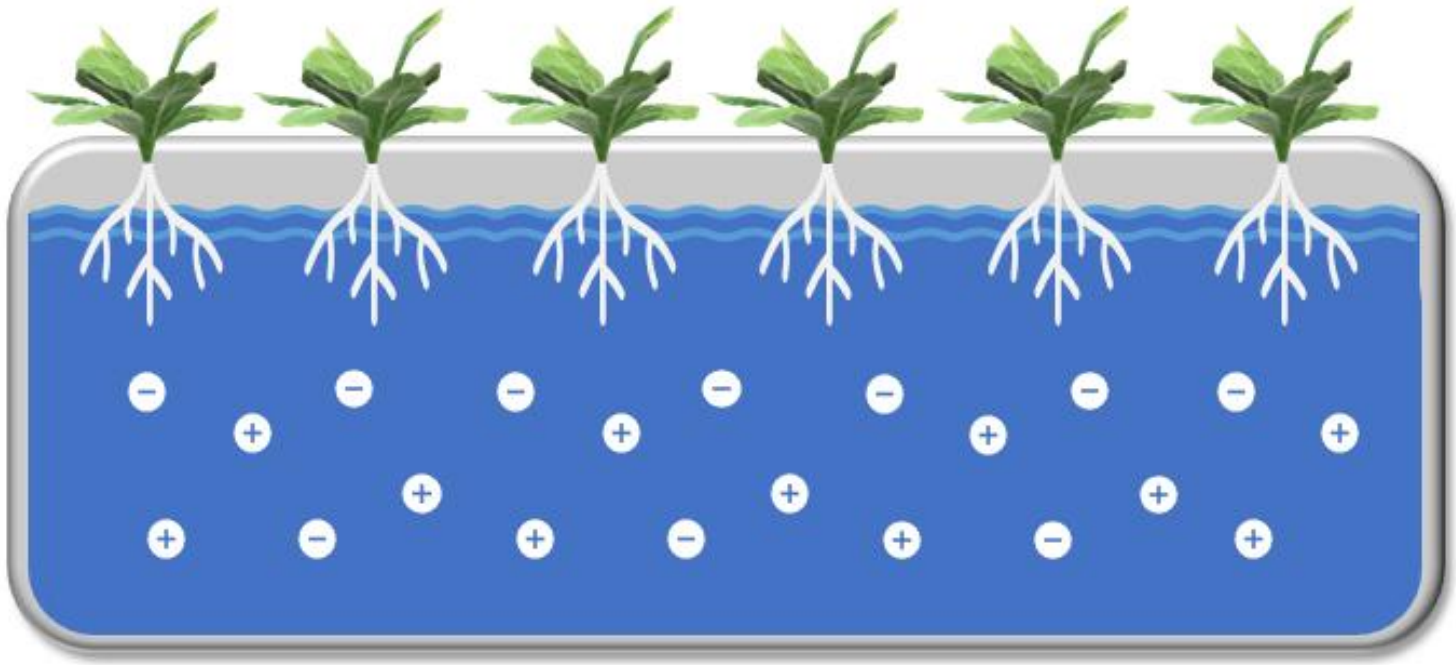
Hydroponic Nutrient Solutions



Review

- Hydroponics uses a complete nutrient solution which contains water and all essential elements
- An essential element is required for a plant to grow and complete its lifecycle

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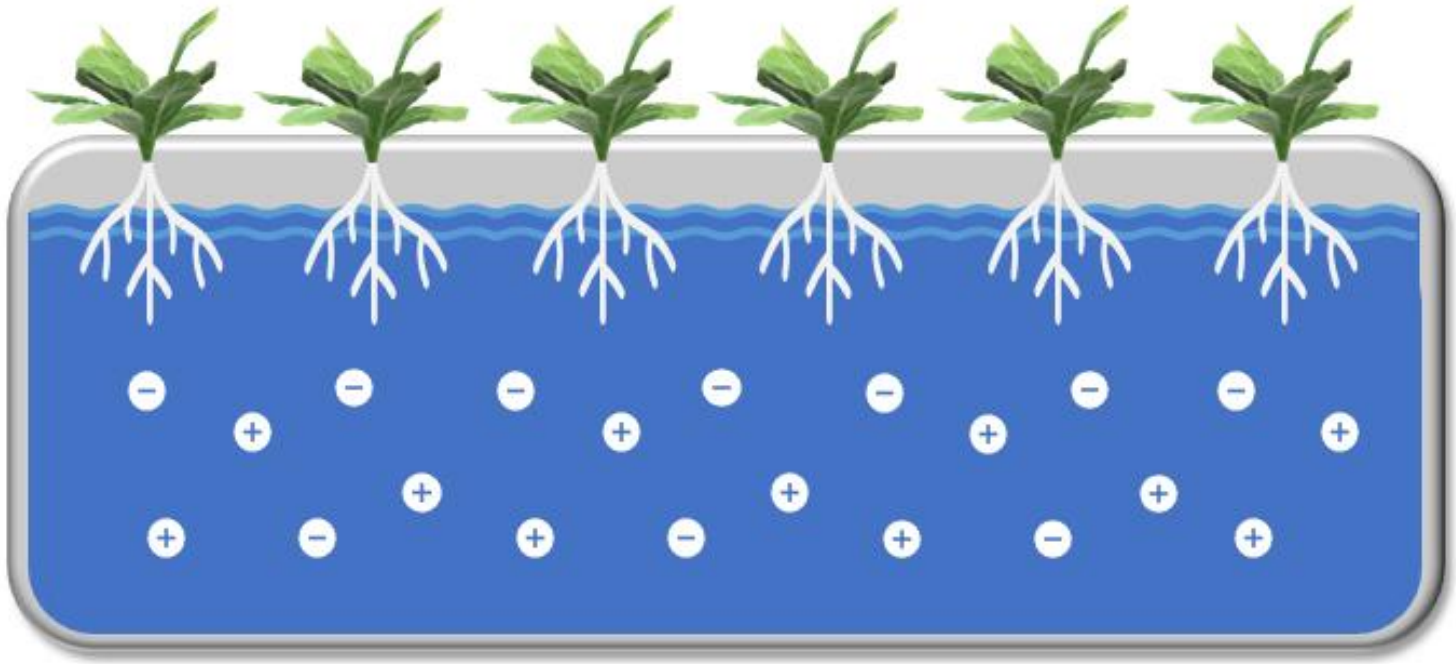
Hydroponic Nutrient Solutions



Review

- 13* essential elements:
  - 6 Macro (N P K Ca Mg S)
  - 7 Micro (Fe Cl B Zn Mn Cu Mo)
- Dissolved in water as inorganic ions for plant roots to uptake

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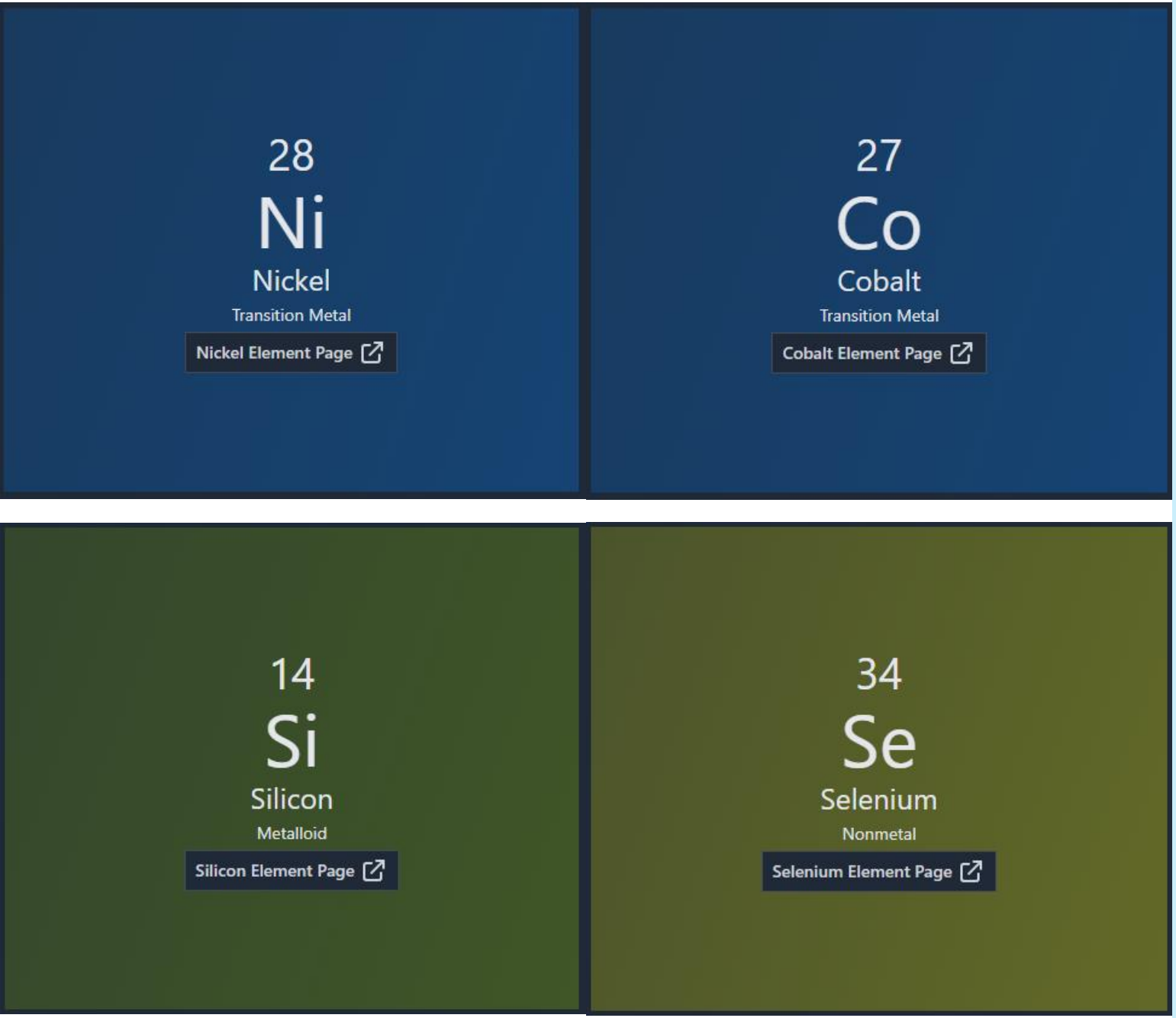

PubChem Periodic Table

Hydroponic Nutrient Solutions

Other Essential Elements

- But there are a total of 17 essential elements for plants
- H, O, C, and Ni do not need to be added to a nutrient solution
- Other elements being considered (Co, Si, Se)…

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Bluelab

Hydroponic Nutrient Solutions

EC and pH

- You can measure the ions in a hydroponic nutrient solution using an electrical conductivity (EC) and pH meter
  - EC measures the total ion concentration
  - pH measures H^+ concentration

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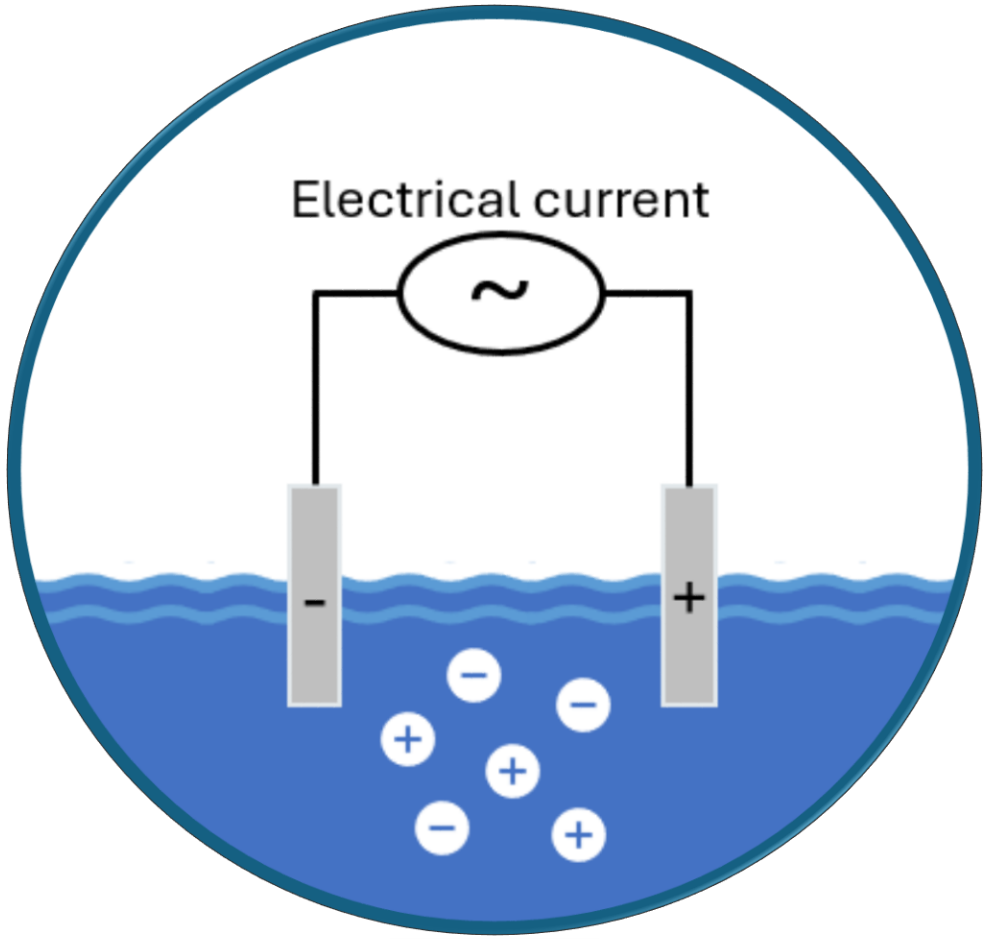
Hydroponic Nutrient Solutions

EC and pH



- An EC meter has electrodes that measure the conductance in a solution (mS/cm)
- The more ions in solution, the greater the conductance
  - Rain water: 0.0 mS/cm
  - Tap water: ~0.3
  - Brackish water: >3.0
  - Seawater: ~50.0

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Hydroponic Nutrient Solutions

EC and pH

Example:	Hydroponic Nutrient Solution	Salty Water	*Are these solutions different?*
EC	1.2 mS/cm	1.2 mS/cm	*They appear to be the same!*
Specific Ions:	N, P, K, etc…	Na, Cl (table salt)	*But, they are very different!*

- An EC range of 1.0 – 2.0 mS/cm is commonly used in hydroponic nutrient solutions
- EC is a quick and easy tool to gauge the concentration of a nutrient solution
- EC does not tell you about specific ions!

Bluelab

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Hydroponic Nutrient Solutions

EC and pH

Hydrion

- pH measures H^+ concentration to determine the acidity (more H^+) or basicity (less H^+) of a solution

- pH ranges from 0-13 and is logarithmic (10x)

  - 7 is neutral (e.g pure water)
  - <7 is acidic (e.g vinegar)
  - >7 is basic (e.g bleach)

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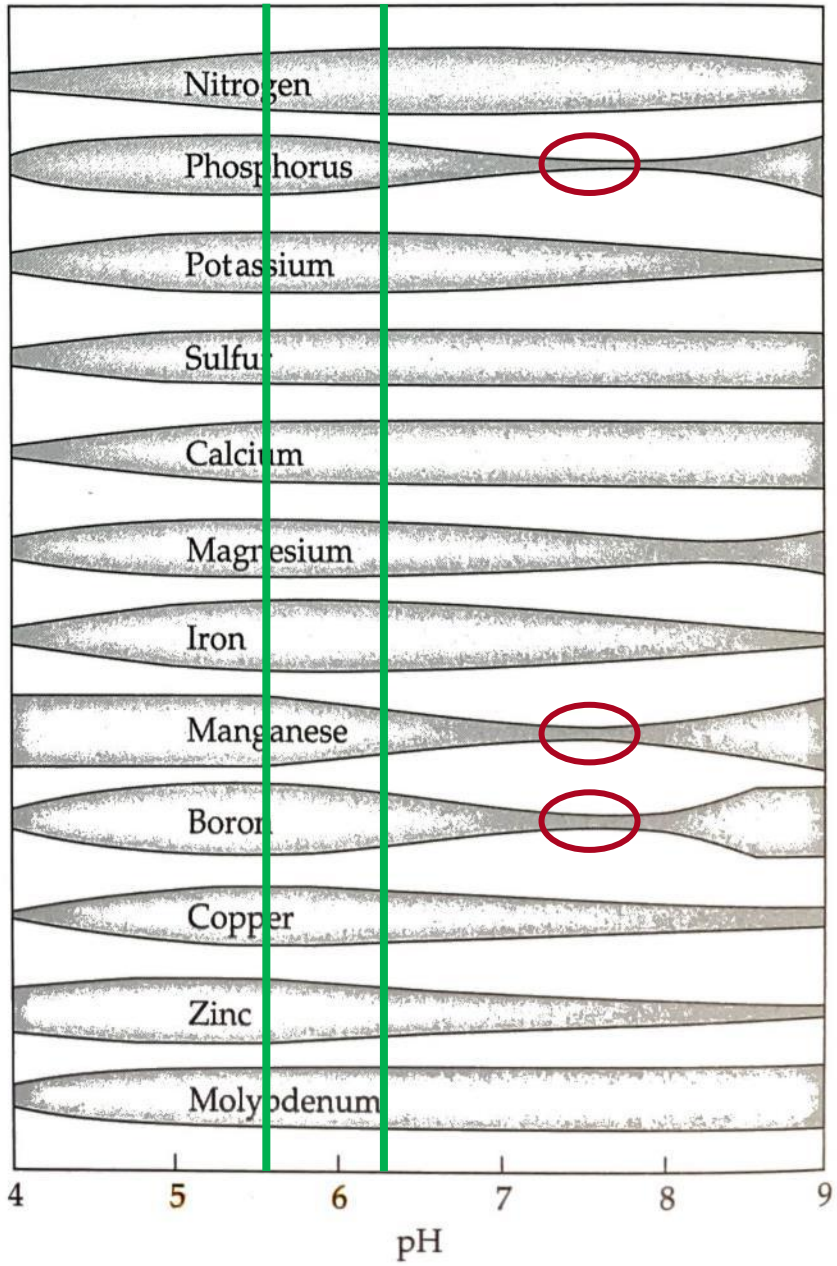
Hydroponic Nutrient Solutions

EC and pH



Mineral Nutrition of Plants

- pH influences nutrient availability for plant root uptake
- P, Mn, and B lockout can occur if pH is too high (~7.5)
- A pH range of 5.6 - 6.3 is commonly used in hydroponic nutrient solutions

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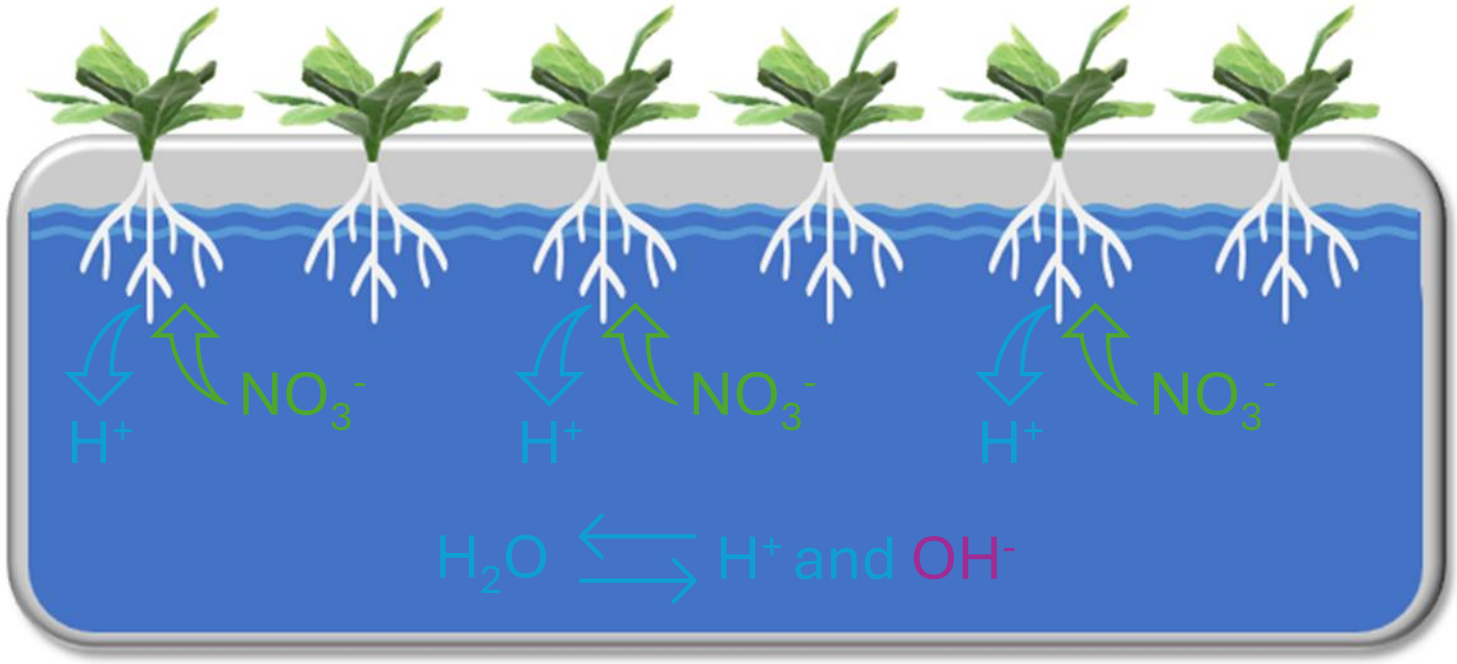
Hydroponic Nutrient Solutions

EC and pH



Hydroponic nutrient solutions have a <u>low buffer capacity</u> which makes pH flux more common

- Therefore, it is common practice to <u>regularly lower the pH by slowly dosing an acid</u>
- However, the pH of a hydroponic nutrient solution is in <u>flux…</u>
  - pH can <u>increase</u> if more water is added
  - pH can <u>decrease</u> due to ion uptake by plant roots

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Hydroponic Nutrient Solutions

Use personal protective equipment (PPE) when handling acids!

General Hydroponics

EC and pH

- Recommended acids for use in hydroponic nutrient solutions:
  - Nitric acid (source of N)
  - Phosphoric acid (source of P)
  - Citric acid (weak but safer handling)

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Hydroponic Nutrient Solutions

Nutrient Solution Recipes

- A recipe refers to the composition of macro and micro nutrients in a hydroponic nutrient solution
- Hoagland's Solution recipe with essential element concentrations (ppm or mg/L)
- TDS / 640 = EC (mS/cm)*

Hoagland's Solution Recipe

	Element	ppm (mg/L)
Macros	N	210
	P	31
	K	235
	Ca	200
	Mg	49
	S	64
Micros	Cl	0.6
	Fe	5.0
	Mn	0.5
	B	0.5
	Zn	0.05
	Cu	0.02
	Mo	0.017
	TDS:	**796**
	EC (mS/cm):	**1.2**

Hoagland and Arnon

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Hydroponic Nutrient Solutions

General Hydroponics

Nutrient Solution Recipes

- Hydroponic nutrient solution recipes can be crop, growth, and tissue dependent
- E.g. the recipe to grow lettuce is different from the recipe to grow tomato
- *With hydroponics you can fine-tune a recipe to grow better and waste less!*

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Hydroponic Nutrient Solutions

Nutrient Solution Recipes

- Leafy greens like lettuce require a single recipe because they grow fast and are harvested before they flower and set seed

- However, a half-strength (1/2x) nutrient solution is commonly used for germination and seedling establishment

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CEAC Hydroponic Leafy Green Recipe			
		1/2x (Half-strength)	1x (Full-strength)
		Week 0 - 2 (Propagation)	Week 2 - 5+ (Production)
	Element	*ppm (mg/L)*	*ppm (mg/L)*
Macros	N	75	150
	P	15	30
	K	100	200
	Ca	80	160
	Mg	25	50
	S	35	70
Micros	Cl	15	30
	Fe	1.0	2.0
	Mn	0.23	0.45
	B	0.18	0.35
	Zn	0.15	0.30
	Cu	0.03	0.05
	Mo	0.03	0.05
	TDS:	**347**	**693**
	EC (mS/cm):	**0.5**	**1.1**
	EC w/ tap water:	**0.9**	**1.5**
	pH (setpoint):	**6.0**	**5.6**

Hooks

Hydroponic Nutrient Solutions

Nutrient Solution Recipes

- CEAC hydroponic leafy green nutrient solution recipe: EC 1.5 mS/cm and pH 5.6
- Includes half-strength (1/2x) for propagation (~2 weeks)
- Full-strength (1x) for production (~3 weeks)

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Hydroponic Nutrient Solutions

Nutrient Solution Recipes

- *Why use a half-strength (1/2x) nutrient solution for propagation?*
- The technique is to incrementally increase the strength (EC) of the nutrient solution as the plant matures to prevent osmotic shock and minimize waste

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Hydroponic Nutrient Solutions

Nutrient Solution Recipes

- For larger flowering and fruiting crops like tomato, it is common to use more than one recipe to support distinct growth stages and plant tissue

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Hydroponic Nutrient Solutions

Nutrient Solution Recipes

- The CEAC hydroponic tomato nutrient solution has three distinct recipes based on different growth stages:

1. Vegetative (leaves and roots)
2. Generative (flowers and fruit)
3. Balanced (mature and continuously producing)

CEAC Hydroponic Tomato Recipes

	Element	1/2x Propagation (Week 0 - 4) ppm (mg/L)	1. Vegetative (Week 4 - 8) ppm (mg/L)	2. Generative (Week 8 - 12) ppm (mg/L)	3. Balanced (Week 12+) ppm (mg/L)
Macros	N	75	150	170	190
	P	20	40	47	47
	K	90	180	270	350
	Ca	80	160	180	200
	Mg	30	60	65	70
	S	45	90	120	140
Micros	Cl	15	30	50	60
	Fe	1.0	2.0	2.5	3.0
	Mn	0.35	0.70	0.70	0.70
	B	0.20	0.40	0.40	0.40
	Zn	0.17	0.33	0.33	0.33
	Cu	0.03	0.06	0.06	0.06
	Mo	0.03	0.06	0.06	0.06
	TDS:	**357**	**714**	**906**	**1062**
	EC (mS/cm):	**0.6**	**1.1**	**1.4**	**1.7**
	EC w/ tap water:	**1.0**	**1.5**	**1.9**	**2.2**
	pH (setpoint):	**6.0**	**6.0**	**5.6**	**6.0**

Hooks

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Hydroponic Nutrient Solutions

Nutrient Solution Recipes

- CEAC Tomato Recipe 1 favors vegetative growth when the plants are young and encourages root and shoot growth and establishment
    - N, P, and Ca are emphasized
    - Mild EC (1.5)
    - Mild pH (6.0)

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Hydroponic Nutrient Solutions

Nutrient Solution Recipes

- CEAC Tomato Recipe 2 favors generative growth when the plants are intermediate size to encourage lots of flower production and fruit setting
    - P, K, and Ca are emphasized
    - Moderate EC (1.9)
    - Lower pH (5.6)

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Hydroponic Nutrient Solutions

Nutrient Solution Recipes

- CEAC Tomato Recipe 3 supports mature plants at full production for sustained balance between vegetative and generative growth
    - N, K, Ca, and Fe are emphasized
    - Higher EC (2.2)
    - Balanced pH (6.0)

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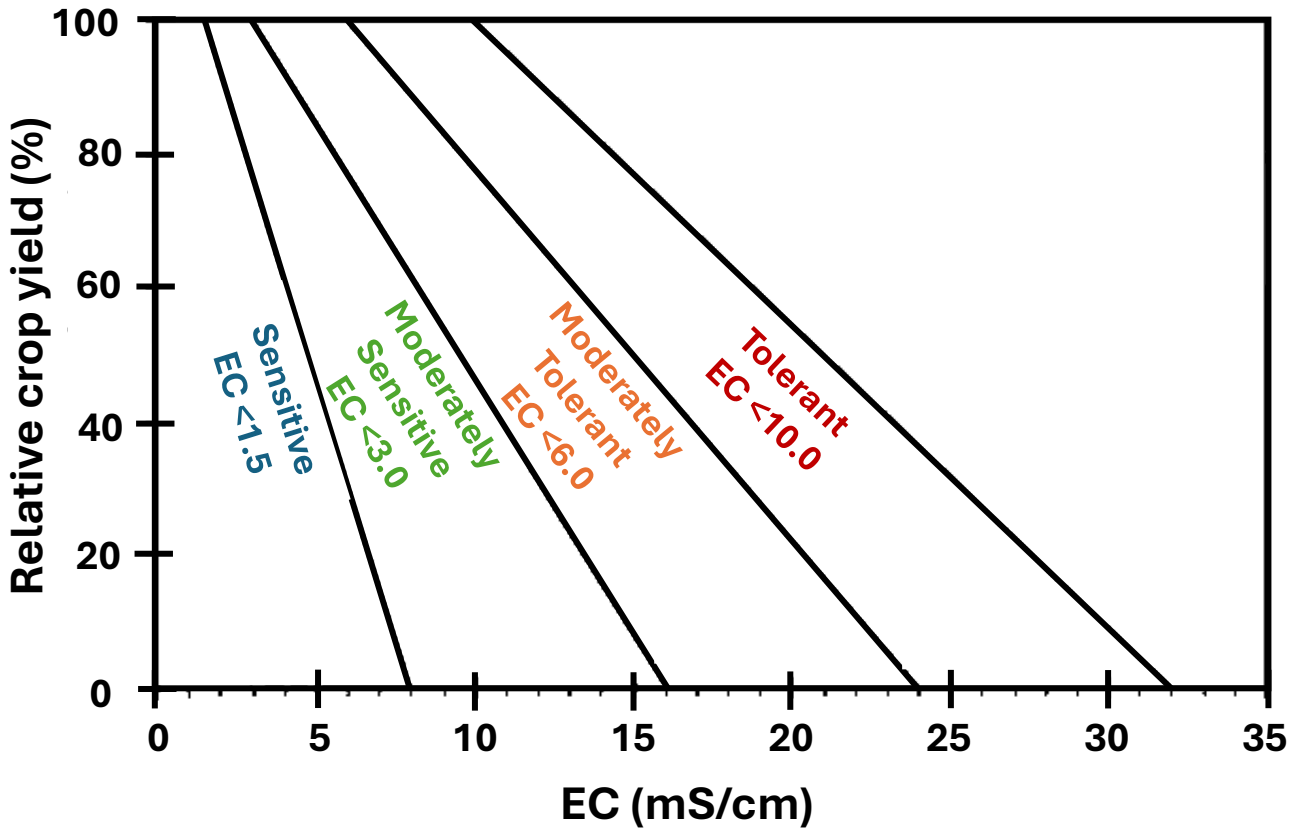
Hydroponic Nutrient Solutions

Nutrient Solution Recipes

- *How do you determine recipes for different crops?*
- Recipes can be adjusted using EC based on crop salinity tolerance
  - Strawberries ~1.0 EC
  - Pepper ~1.5 EC
  - Tomato and Cucumber ~2.4 EC

FIG. 1. Divisions for classifying crop tolerance to salinity



Maas and Grattan

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Hydroponic Nutrient Solutions

Concentrated Stocks

- Typically, a nutrient solution is not prepared directly in a hydroponic system reservoir
- Instead, concentrated liquid stocks are prepared
- Stocks are practical and maintain a safe separation between the plants and supply of concentrated nutrient solution

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Hydroponic Nutrient Solutions

Concentrated Stocks

- Nutrient solution stocks are commonly prepared in a set of three:
  - **Stock A** can include P, K, Mg, S, and most micros (cloudy appearance)
  - **Stock B** can include N, K, Ca, Cl, Fe (rust/red color)
  - **Stock C** is used for acid

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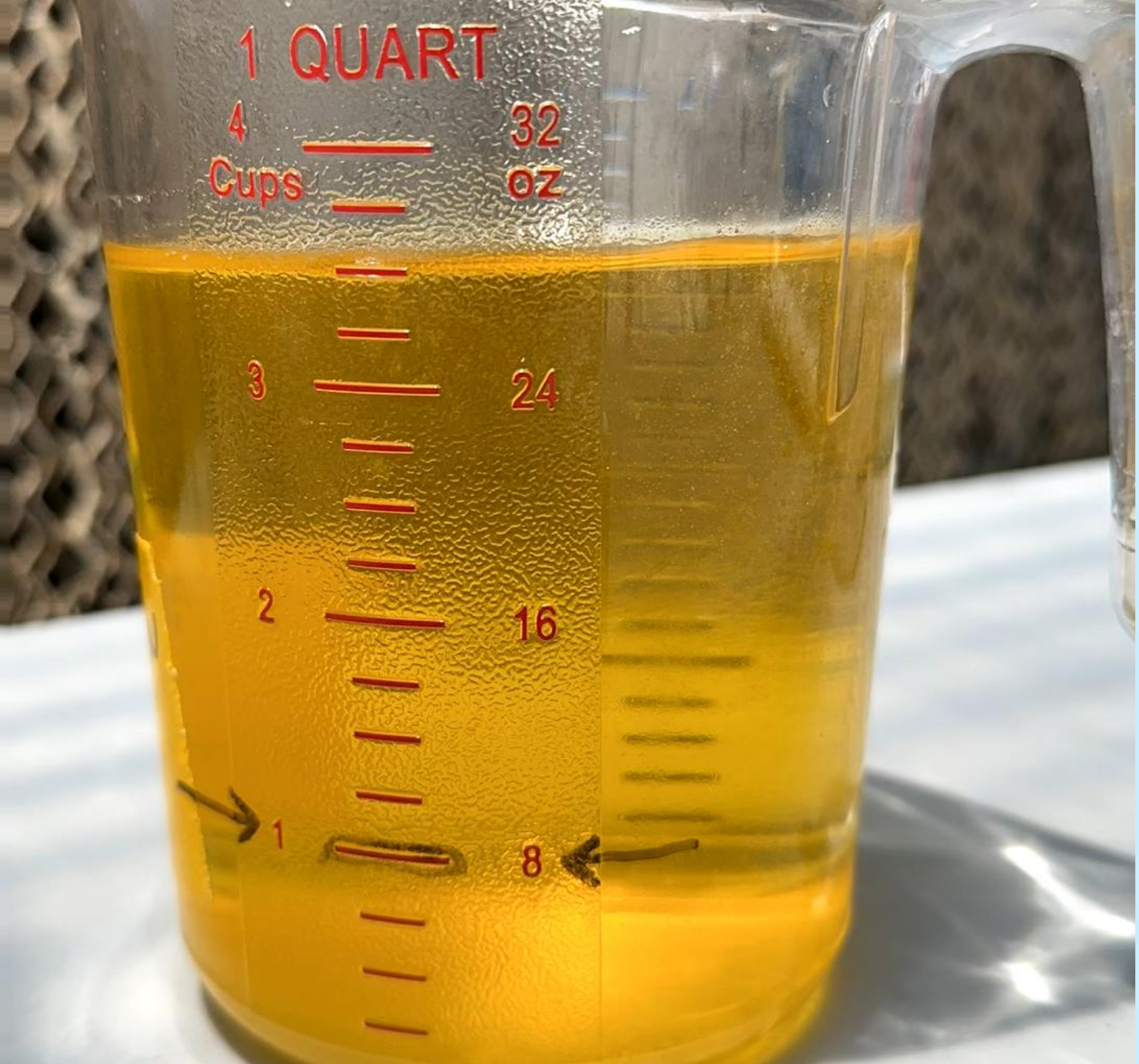

Hydroponic Nutrient Solutions

Concentrated Stocks

- *Why separate the stocks?*
- For greater solubility and concentrations, up to 200x
- When concentrated, calcium must be separated from sulfates, to prevent the precipitation of gypsum crystals ($CaSO_4$)

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Hydroponic Nutrient Solutions

Concentrated Stocks

- Stocks can range in volume and concentration, depending on the application
- 5-gal (18.9L) stocks at 100-150x are common for small scale systems
- 100+ gal (379+ L) stocks at 200x are common for medium to large scale systems

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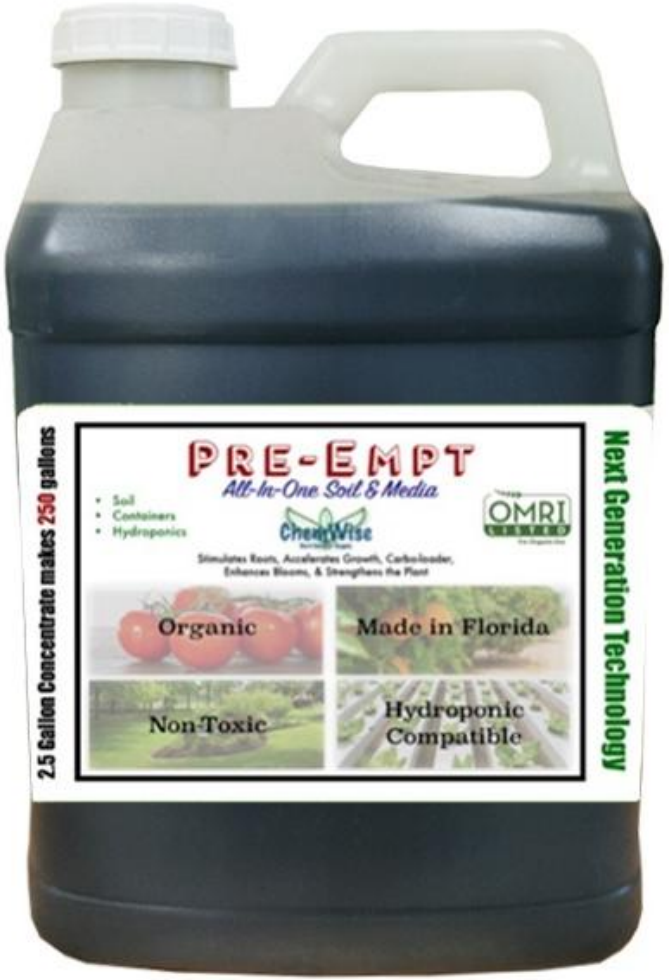
Hydroponic Nutrient Solutions



Concentrated Stocks

- *How do you make stocks?*
- You can buy concentrated nutrient solution in wet or dry forms
- But it is recommended to prepare stocks using individual dry fertilizer salts

Coastal Fertilizer, Hort Americas

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Hydroponic Nutrient Solutions

Concentrated Stocks

- Dry fertilizer salts can be mixed with water to prepare concentrated stocks
- Individual salts can be more economical, versatile, and allow for custom recipes

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Hydroponic Nutrient Solutions

Stock	Fertilizer Salt	Chemical Formula	Element
Stock A	Potassium phosphate	KH_2PO_4	K, P
	Potassium sulfate	K_2SO_4	K, S
	Magnesium sulfate	$MgSO_4\,7H_2O$	Mg, S
	Mangenese sulfate	$MnSO_4\,4H_2O$	Mn
	Boric acid	H_3BO_3	B
	Zinc sulfate	$ZnSO_4\,7H_2O$	Zn
	Copper sulfate	$CuSO_4\,5H_2O$	Cu
	Sodium Molybdate	$MoNa_2O_4$	Mo
Stock B	Potassium nitrate	KNO_3	K, N
	Calcium nitrate	$CaH_4N_4O_9$	Ca, N
	Calcium chloride	$CaCl_2\,2H_2O$	Ca, Cl
	Iron chelate	EDDHA 6%	Fe

Concentrated Stocks

- Here is a list of recommended dry fertilizer salts that can be used to prepare hydroponic nutrient solution stocks
- You need to calculate the mass of each fertilizer salt!
- *See your hydroponic nutrient solution calculation sheet provided!*

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Hydroponic Nutrient Solutions

Concentrated Stocks

- Here are the calculated masses for each fertilizer salt needed to prepare concentrated stocks
- *Note, masses of Stock A and B are relatively similar for solubility*

TGH: Mix in 80-Gal (303L) Stocks @200x Concentration				
	Tomato Recipe:	1. Vegetative	2. Generative	3. Balanced
Stock	Fertilizer Salt	Mass (g)	Mass (g)	Mass (g)
Stock A	KH_2PO_4	10650	12514	13313
	K_2SO_4	1200	7600	5000
	$MgSO_4\,7H_2O$	30728	36873	43019
	$MnSO_4\,4H_2O$	172	172	172
	H_3BO_3	139	139	139
	$ZnSO_4\,7H_2O$	88	88	88
	$CuSO_4\,5H_2O$	14	14	14
	$MoNa_2O_4$	8	8	8
Stock B	KNO_3	16800	19000	24600
	$CaH_4N_2O_3$	23700	25100	29600
	$CaCl_2\,2H_2O$	2200	4800	6000
	EDDHA 6%	2020	2525	3030

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Hydroponic Nutrient Solutions

Concentrated Stocks

- You know why concentrated stocks are important
- You know how they are setup, typically as stocks A, B, and C
- You know they are prepared using dry fertilizer salts
- *But how do you actually make them?*

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Hydroponic Nutrient Solutions

Concentrated Stocks

- How to prepare hydroponic nutrient solution stocks:

1. Wear appropriate PPE!
2. Weigh the calculated mass of dry fertilizer salts
3. Add water to fill the empty stocks no more than ~2/3
4. Slowly pour in the dry fertilizer salts
5. Mix thoroughly!
6. Top-off with water

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Hydroponic Nutrient Solutions

Concentrated Stocks

- Salts can be difficult to completely dissolve in the stock solution at high concentrations (~200x)
- Warm water, aeration, and constant mixing can help
- Can be done by hand, but a mixing pump is recommended!

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Hydroponic Nutrient Solutions

Fertigation for Tomatoes

- *What's next?*
- Concentrated stocks are diluted and delivered to the plants = Fertigation
- For hydroponics, fertigation is always used in the form of a complete nutrient solution

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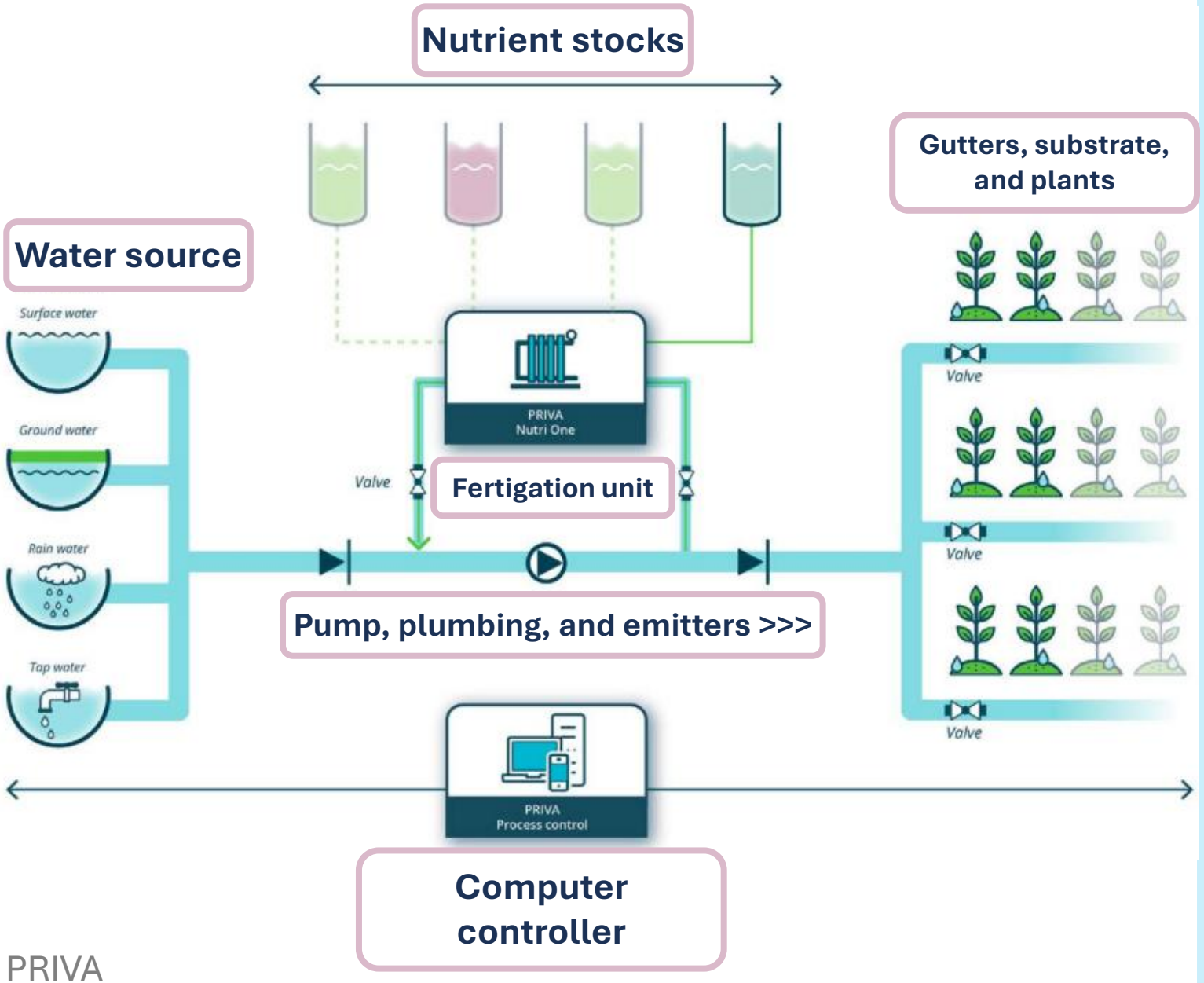
Hydroponic Nutrient Solutions

Fertigation for Tomatoes

Overview of hydroponic drip systems that utilize fertigation:

- Water source
- Nutrient stocks
- Fertigation unit
- Pump, plumbing, and emitters
- Gutters, substrate, and plants
- Computer controller



PRIVA

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Hydroponic Nutrient Solutions

Fertigation for Tomatoes

- An example of a fertigation unit for a hydroponic drip system
- The fertigation unit mixes water and stocks to make a nutrient solution based on EC and pH setpoints, and then delivers it to the plants in “shots”

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Hydroponic Nutrient Solutions

Fertigation for Tomatoes

- The concentrated stocks can be dosed via injectors, peristaltic pumps, or Dosatrons
- Stocks A and B must be dosed equally to the fertigation unit for accurate mixing of your nutrient solution recipe!

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Hydroponic Nutrient Solutions

Fertigation for Tomatoes

- Pressure compensating emitters are used for uniform distribution of nutrient solution to each plant throughout the growing area

- For vine crops, a common emitter rate is 1 GPH (gallon per hour) or ~4 LPH

Netafim

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Hydroponic Nutrient Solutions

Fertigation for Tomatoes

- *Nutrient solution shots: How much and how often?*
- Rule of thumb, “A little, but often”
- Each shot lasts 3 min @ 1 GPH = 190 mL per plant
- Moves water, nutrients, and dissolved oxygen through the substrate for the plant roots

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Hydroponic Nutrient Solutions

Fertigation for Tomatoes

- The frequency of fertigation shots can be controlled by a timer, moisture, or light sensor
- The goal is to efficiently deliver nutrient solution to the plants for optimum growth
- Example: Fertigation shot every 30 min from an hour after sunrise to an hour before sunset*

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Village Farms

Hydroponic Nutrient Solutions

Fertigation for Tomatoes

- Drip hydroponic systems were developed to support larger crops with extended production cycles such as tomato

- Larger substrate and minimal solution characterize these systems

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Hydroponic Nutrient Solutions

Fertigation for Tomatoes

- Gutters are the primary growing unit in a drip system to support larger substrate slabs
- Gutters are raised for ergonomics and decline (~1%) to collect solution drainage
- Drip lines with stakes are used to “drip” solution to the substrate (one per plant)

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Fertigation for Tomatoes

- Drip system variants can utilize pots, bags, or buckets to accommodate various substrate material
- Small-scale drip system variants can also simply use a recirculating reservoir of nutrient solution

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Fertigation for Tomatoes

- Drip systems are versatile and can grow a variety of exciting crops including tomato, pepper, cucumber, melons, squash, eggplant, cut flowers, hops, cannabis, and more!

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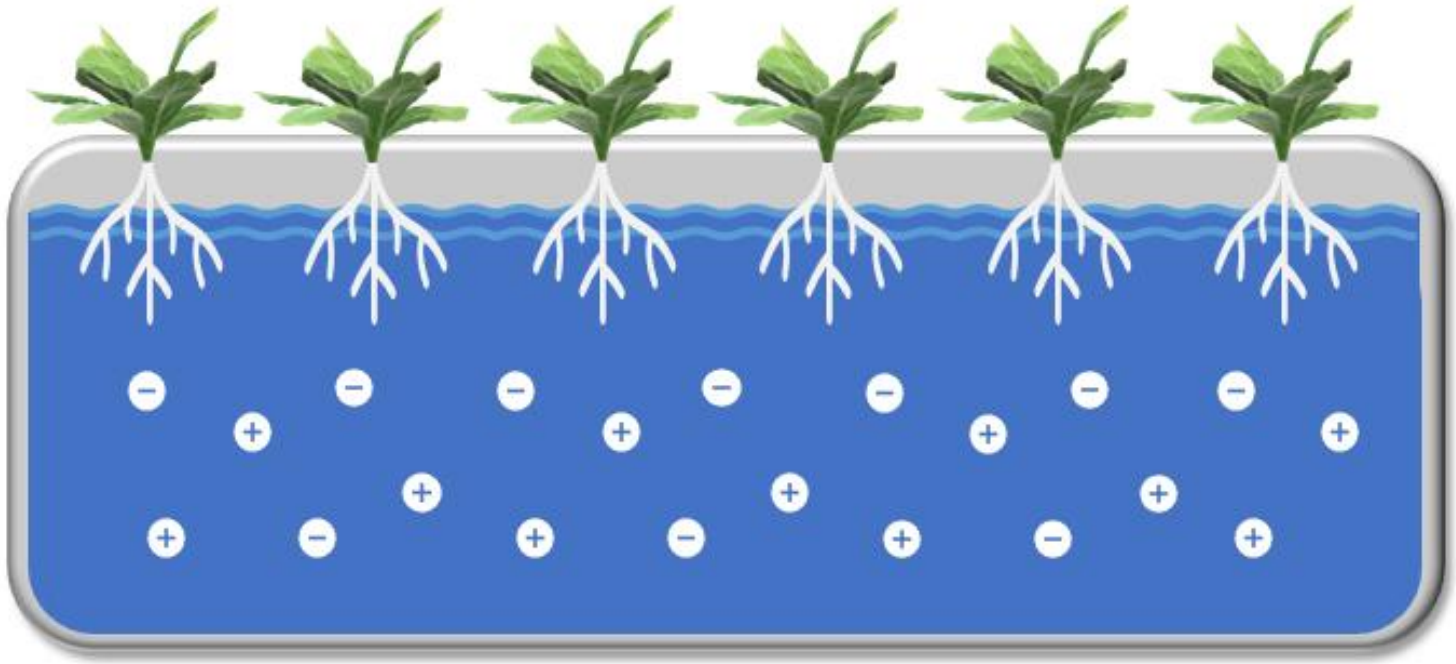

Module 3
Hydroponic Nutrient Solutions

2026 Greenhouse Hydroponic Tomato Workshop with Dr. Triston Hooks

References

- *Resh, 2022, Hydroponic Food Production*
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