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Hydroponic Nutrient Solutions and Crop Care

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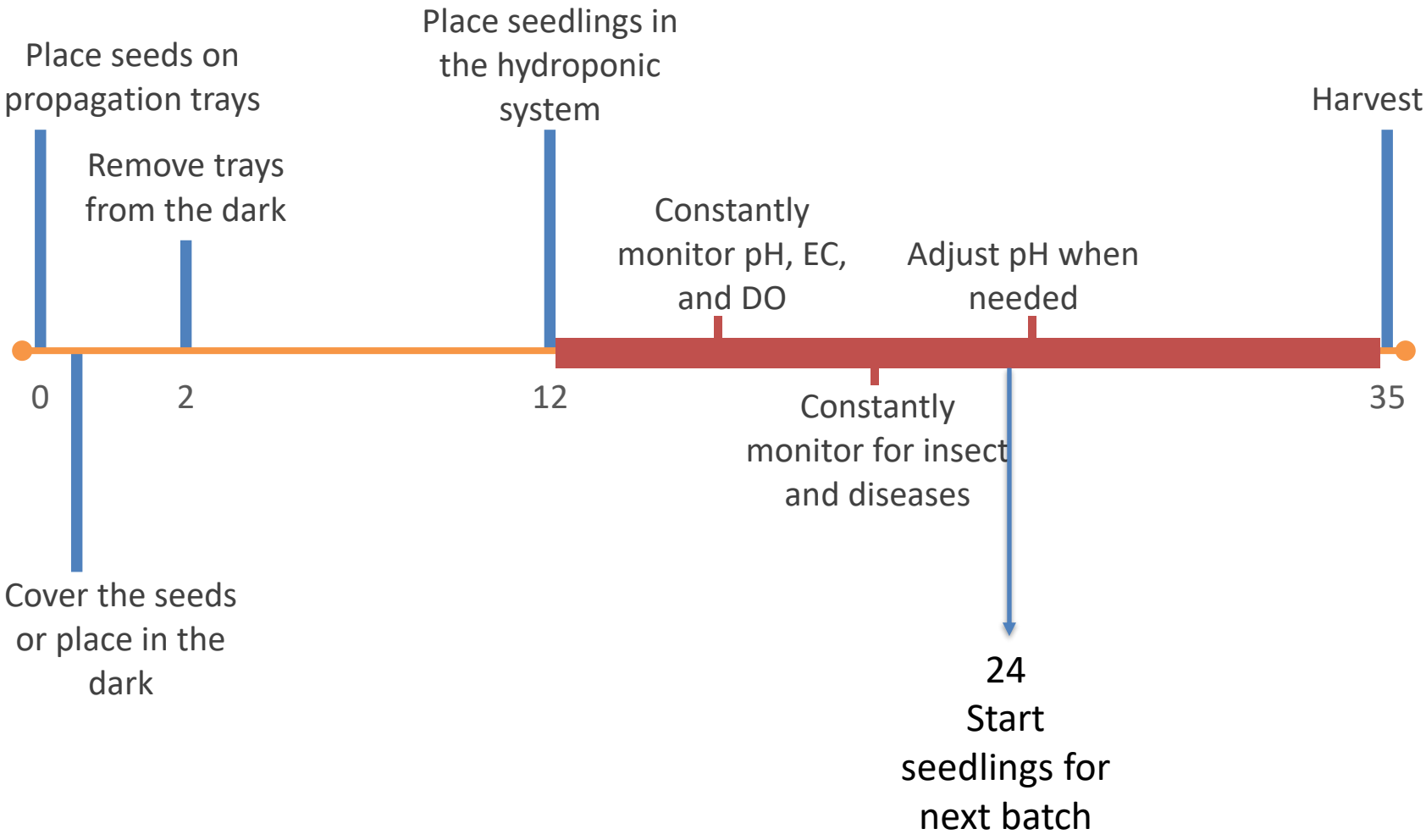
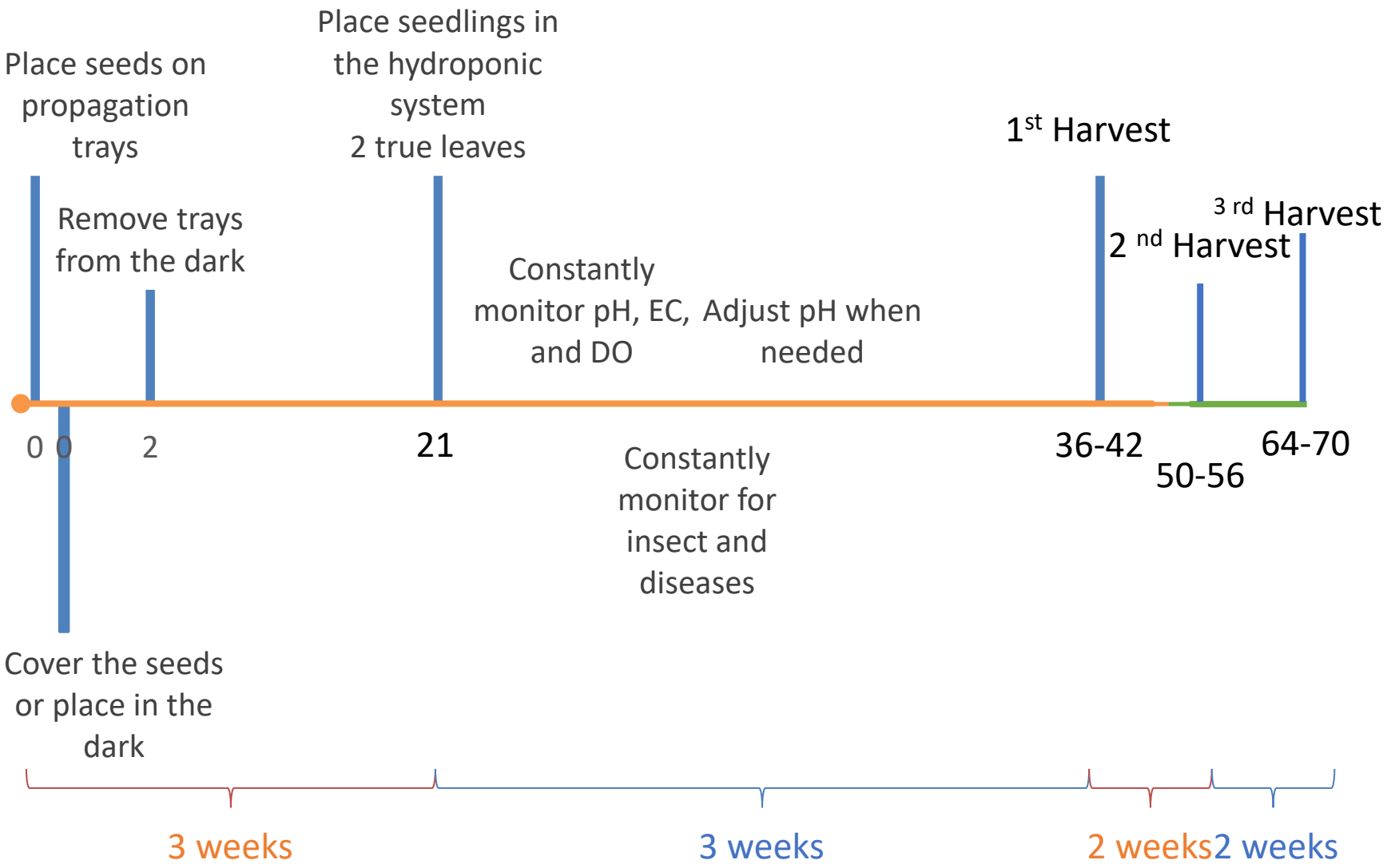
Hydroponic lettuce production timeline

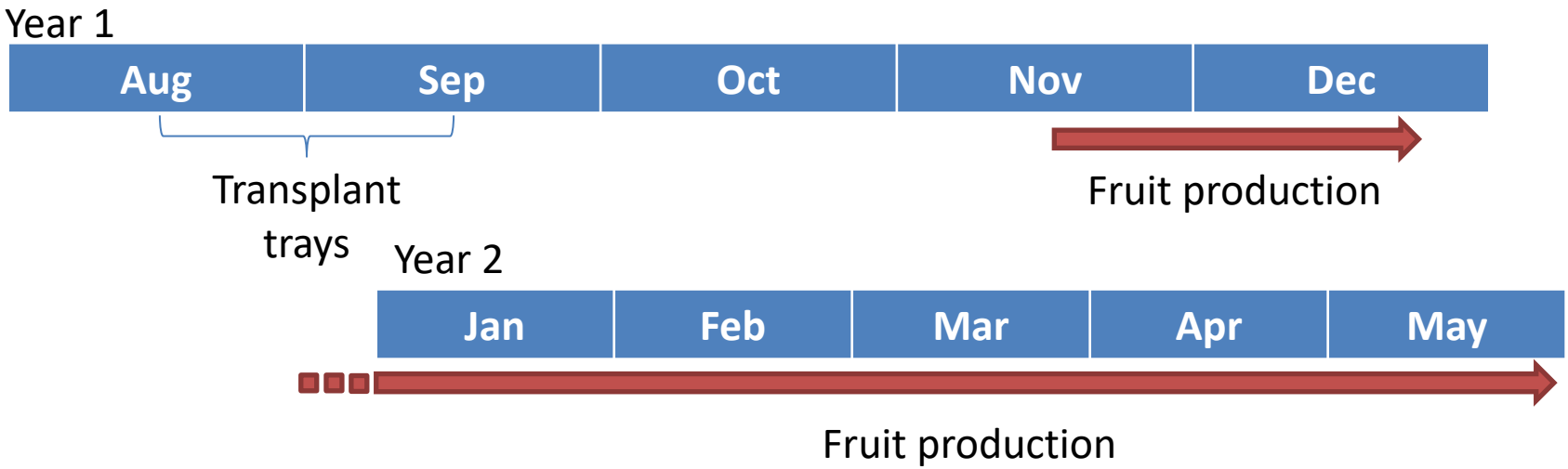


Hydroponic basil production timeline



Source: Kubota OSU

Hydroponic strawberry timeline



Harvest every other day

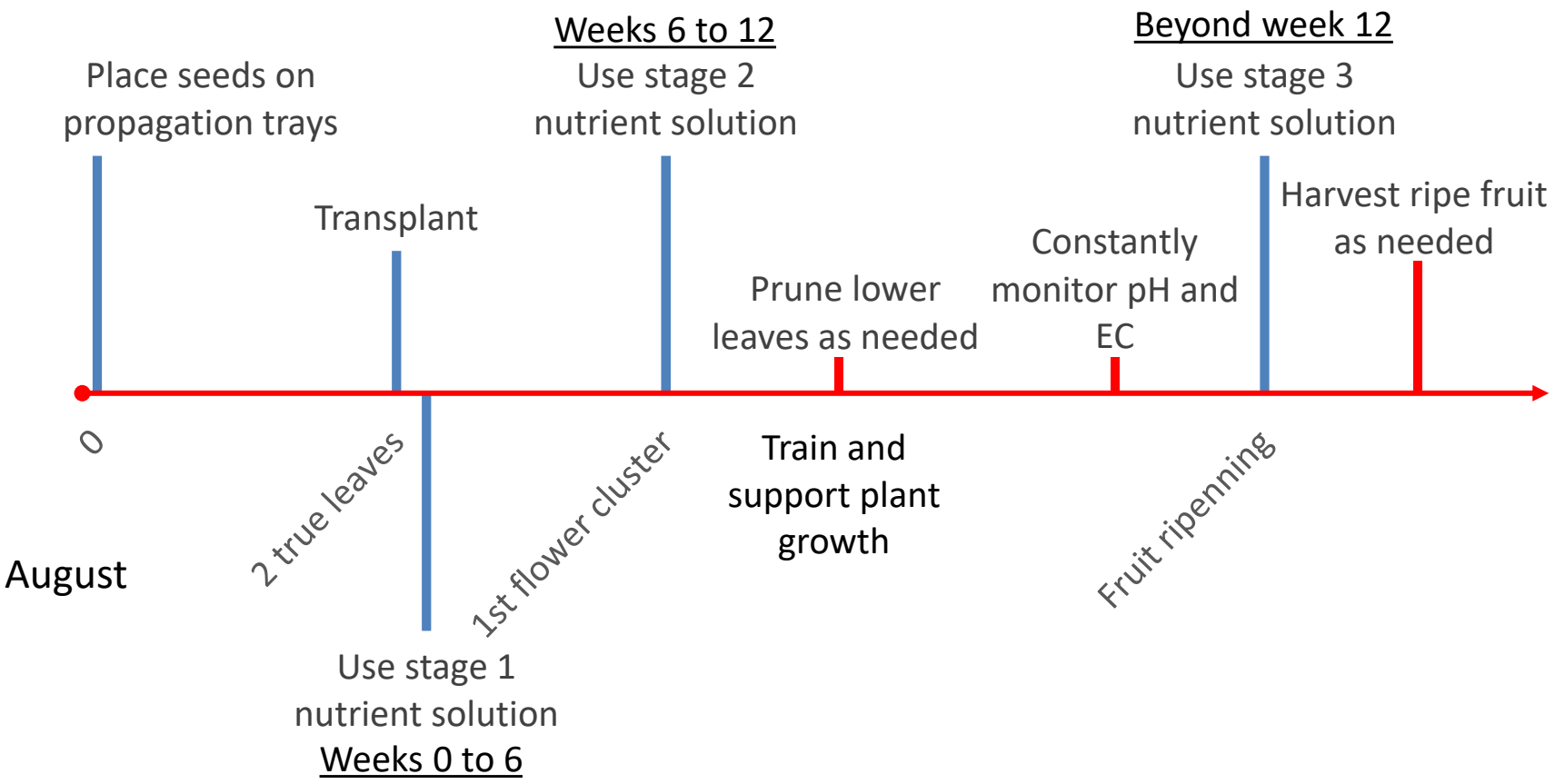
Greenhouse end of harvest season (May): hot summer temperatures and field crop season

Warm temperatures (>86°F)= flower inhibition and poor taste (night temperature>55 ° F)

Off-season activities: clean, sanitize, and propagate runners (released varieties)

Does the harvest season end in an indoor farm?

Hydroponic tomato production timeline



Topics

- Nutrient solutions definitions
  - pH
  - Electrical conductivity
  - Dissolved oxygen
  - Alkalinity
- Nutrient requirements
- Making nutrient solutions
- Monitoring nutrient solutions
- Plant production timeline and steps
- Common problems

Water + Fertilizers= Nutrient Solution

A great nutritional program begins with good water quality.

The purpose of a nutrition program is to :

- ✓ Provide all essential elements.
- ✓ Provide elements in optimum quantities for plant growth
- ✓ Promote availability and absorption of nutrients.
  - → pH management
  - → Root health
  - → Water uptake
  - → Proper mixing

Comfort zone

- Chill weather
- Awesome views
- Cozy
- Nice warm cup of coffee

Plants also have comfort zones!

Keeping plants in their comfort zone

1. Provide adequate amounts of essential nutrients
   - Proper mixing of fertilizers
   - Electrical conductivity (EC) to check levels
2. Monitor and adjust the pH of the nutrient solution
   - Affects availability and absorption of nutrients
3. Manage the water temperature and dissolved oxygen
   - For healthy root systems
4. Adequate lighting
5. Air flow, humidity, and temperature
   - Water uptake

Nutrient solutions

- Factors affecting solutions:
  - Initial water quality
  - pH
  - Electrical conductivity (EC)
  - Dissolved oxygen (temperature)
  - Crop requirements by growth stage
  - Water alkalinity (hardness)
- Preparing and monitoring nutrient solutions
- Organic fertilizers and aquaponics

Water source quality

Water quality: depends on it's intended use
What is ***good*** water quality?
How do you know if your water source is good?

Parameter	Optimum range
pH	5.5-7
EC (dS/m)	0.2-0.8
Alkalinity	40-160 ppm $CaCO_3$ equivalent
Dissolved oxygen	>6ppm
Total suspended solids	<30 ppm

Test your water source!

Problem Ions

Element	Critical level ppm (mg/L)
Sodium (Na^{+})	< 50
Chlorine (Cl^{-})	< 70
Sulfates ($SO4^{-}$)	< 90
Boron (B)	< 0.5
Fluor (F)	< 1.0
Calcium (Ca^{++})	< 150
Magnesium (Mg^{++})	< 75
Iron (Fe^{+++})	<1
Manganese	<1

EMW-400 : Water Irrigation Suitability

Components		Results mg/L	meq	Target Ranges (mg/L)	Acceptable (mg/L)
MAJOR CATIONS					
Potassium	K	3.73	0.10		<100
Calcium	Ca	11.22	0.56	25 - 75	<150
Magnesium	Mg	3.23	0.27	10 - 30	<50
Sodium	Na	40.54	1.76	0 - 20	<50
MAJOR ANIONS					
Phosphate	PO4	0.71	0.02		<90
Sulfate	SO4	18.97	0.39	0 - 120	<240
Chloride	Cl	41.00	1.14	0 - 20	<140
HCO3 Alkalinity	HCO3	45.87	0.75		
CO3 Alkalinity	CO3	0.00	ND		
Ammonium Nitrogen	NH4-N	ND			<10
Nitrate Nitrogen	NO3-N	ND			<75
pH	pH	7.10		5.50 - 7	4-10
Soluble Salts	EC	0.26		0.20 - 0.80	0-1.5
Total Alkalinity	CaCO3	37.60		40 - 160	0-400
Iron	Fe	0.16		< 1	<4
Manganese	Mn	0.01		< 1	<2
Boron	B	0.04		< 0.10	<0.5
Copper	Cu	0.06		< 0.10	<0.2
Zinc	Zn	0.05		< 0.50	<1
Molybdenum	Mo	0.02		< 0.10	<0.2
Aluminum	Al	0.16			

pH

Affects nutrient availability

Keep it between 5.5 and 6.5 for most crops

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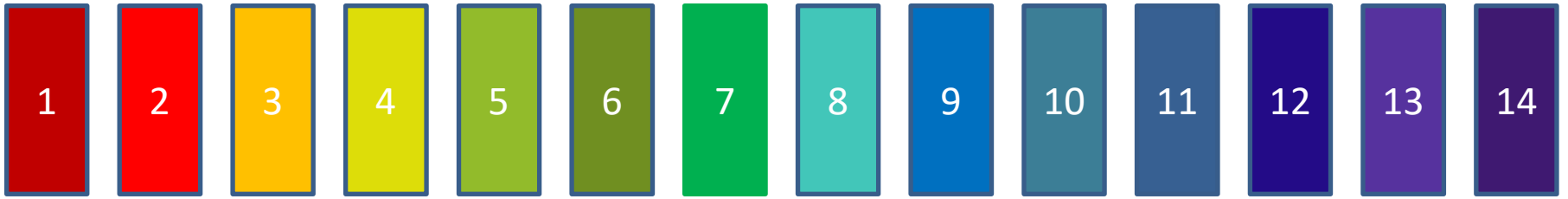
What is pH?

- Represented by a scale that ranges from 1 to 14.
- Is a measure of the concentration of hydrogen ions (H+).
- At pH 7 the solution is said to be neutral, below 7 it becomes more acidic and above 7 it becomes basic.



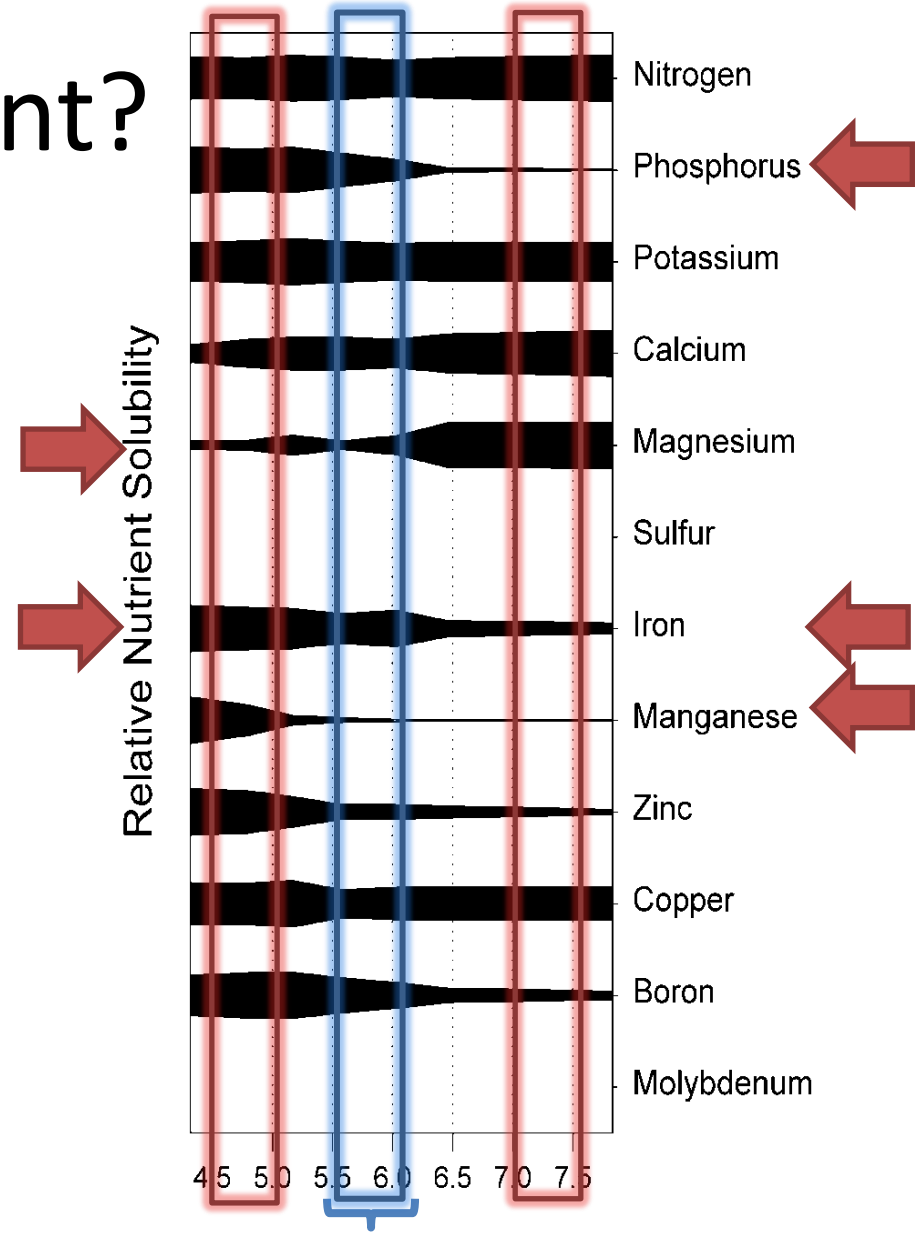




Why is pH important?

- Solubility (availability) of nutrients.

- Plant health (specificity):
- Excessive → toxicity
- Insuficiency → deficiency



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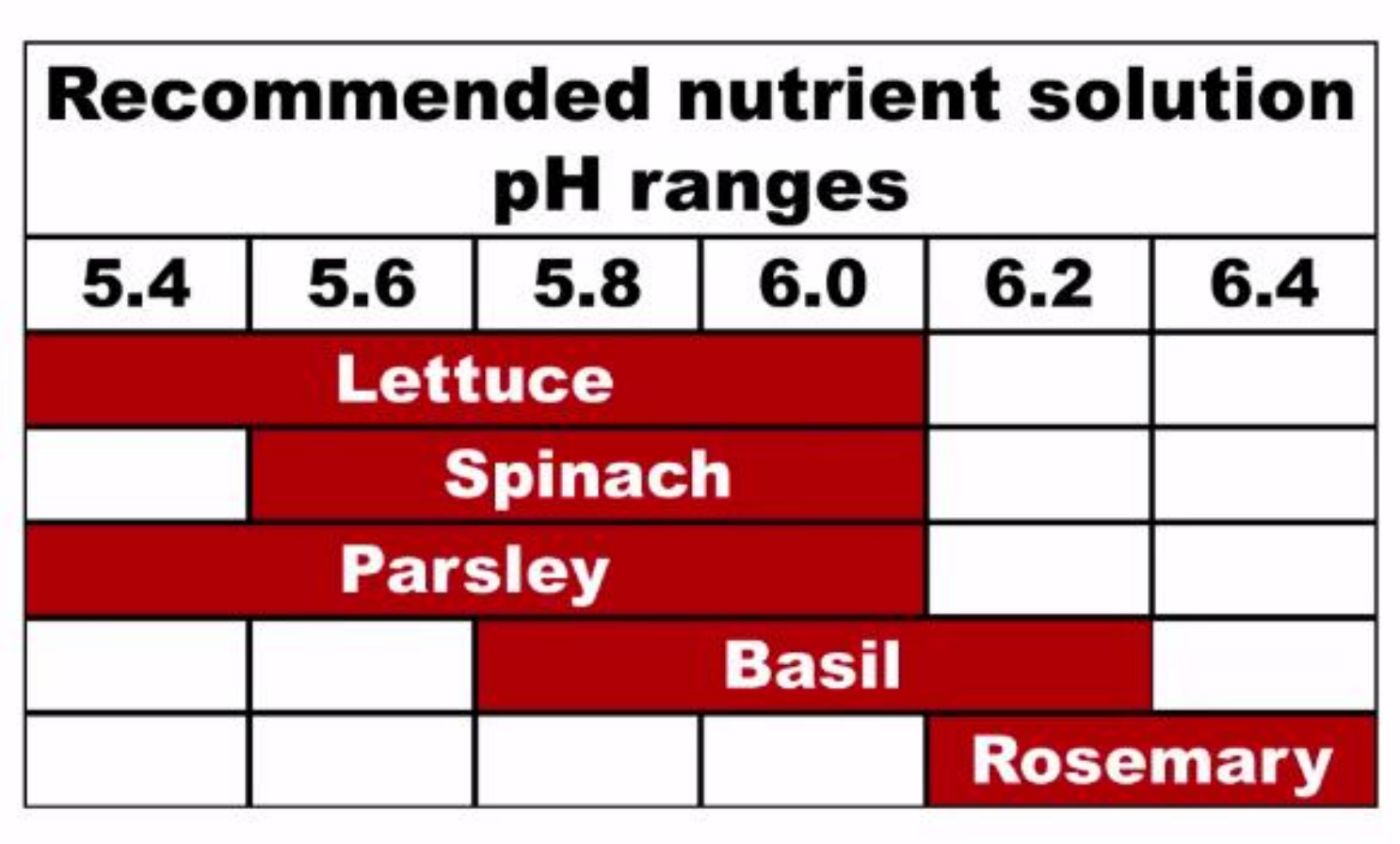
Optimum pH


Recommended nutrient solution pH ranges
5.4
5.6
5.8
6.0
6.2
6.4
Lettuce
Spinach
Parsley
Basil
Rosemary

Electrical conductivity (EC)

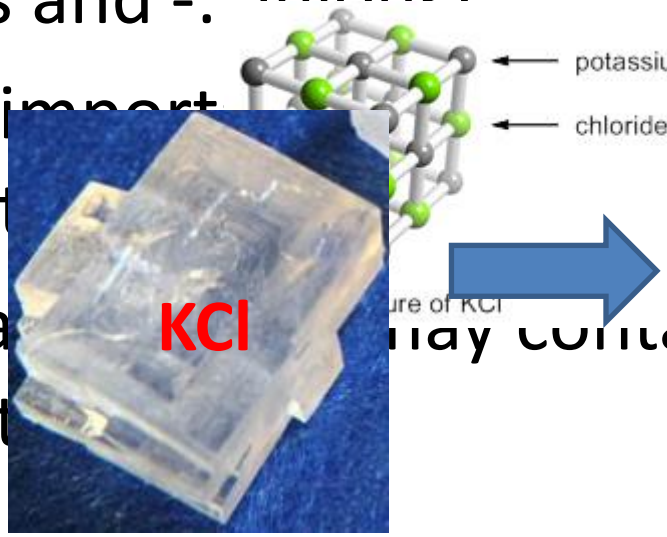
Serves as indicator of nutrient load

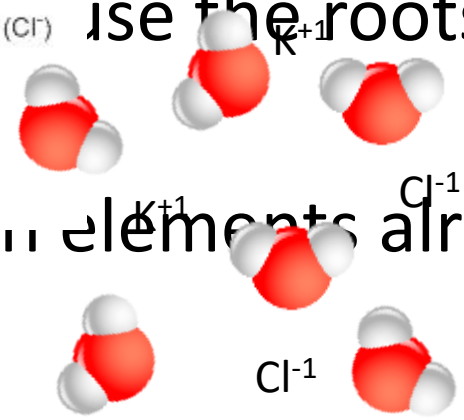
Did you mix the fertilizers correctly?

Fertilizers are salts!

- Ionic bond: elements with positive charge attach to elements with negative charge= SALTS!
- Water molecules break the ionic bond so salts dissolve into their charged state or ions (+: cations and -: anions)
- This is import[illegible] use the roots of plants t[illegible]
- The wa[illegible] may contain elements already in solut[illegible]

$$K^{+1} + Cl^{-1} \rightarrow KCl$$



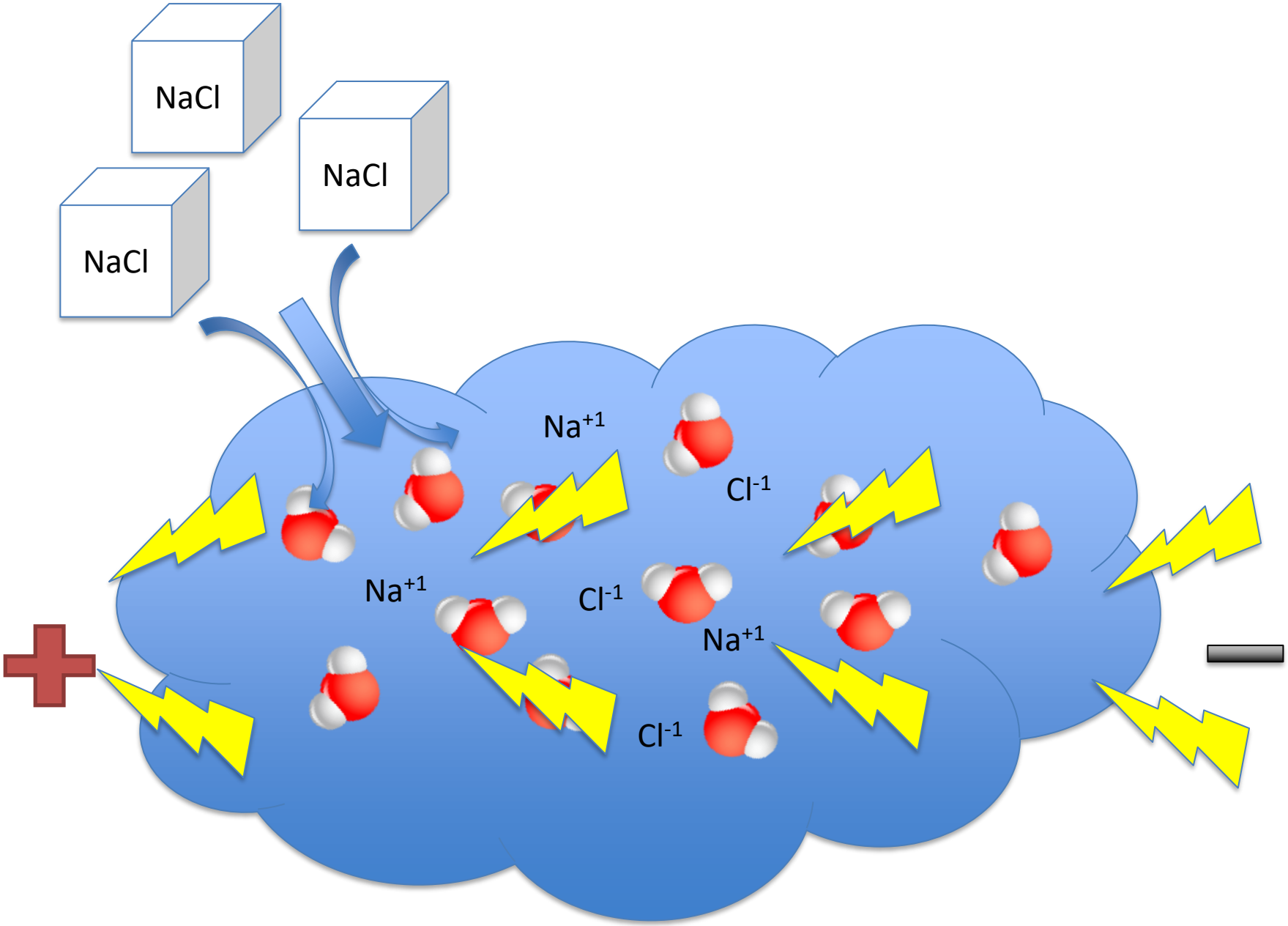


What is Electrical Conductivity (EC)?

- EC is used to measure a solution's ability to conduct electricity.
- A solution with high salt concentration will conduct more electricity. (Remember fertilizers are salts).

More dissolved nutrients=More electricity flow!

(1 mS/cm = 1000 µS/cm = 1dS/m=1 mmhos/cm = 1000 µmhos/cm)


NaCl
NaCl
NaCl
Na^{+1}
Cl^{-1}
Na^{+1}
Cl^{-1}
Na^{+1}
Cl^{-1}

Why is EC important?

- EC used as an indicator of the total salt concentration in solution. It doesn't provide information of which salts.
- Ions that contribute to EC:
  - In water: Ca^{++}, Mg^{++}, SO_4^-, Na^+, Cl, HCO_3-
  - In fertilizers: NO_3^-, NH_4^+, PO_4, K^+, Ca^{++}, Mg^{++}, SO_4, Cl^-

Directions for Use

Selecting the correct fertilizer program – The chemical composition of the irrigation solutions applied to crops has a major influence on the nutrients available to plants in the long term. First, send a sample of your irrigation water to The Everris Testing Lab. Test results will indicate your ABC Water Type (1-4)™ that can be matched with a similar indicator that appears on the front of each bag of Everris Water Soluble Fertilizer. Selecting a fertilizer based on this water type will ensure you experience the best results from your fertilizer program.

Selecting the correct concentration – The correct fertilizer concentration for a particular growing operation will depend on a number of factors including, feeding frequency, crop type, crop stage, growing media, pot size, leaching fraction and environmental conditions. Generally, fertilizer should be applied at concentrations necessary to sustain optimal root zone nutrient levels and quality plant growth. Continuous feeding provides a more uniform plant nutrition program and is recommended over periodic feeding. See Table #1 for general recommendations for crop types.

TABLE 1 Recommended Feeding Rates

Crop Type	Constant Liquid Feeding ppm N	Periodic Feeding ppm N
Bedding Plants	50 – 150	150 – 250
Containerized Woody Plants	50 – 100	200 – 350
Flowering Pot Crops	200 – 300	300 – 450
Potted Foliage	150 – 200	250 – 300
Plugs (All Types)	50 – 125	175 – 225
Landscape/Outdoors	200 – 300	400 – 600

Mixing Concentrated Stock Tanks – Most growers make up concentrate solutions in a stock tank and use an injector system to achieve the correct final concentration. For best results:

TABLE 2 Weight (In Ounces) of Product Needed To Mix One Gallon of Concentrate

Target Fertilizer Concentration (ppm N) After Dilution	Injector Ratios 1:15	1:100	1:200	EC mmhos/cm of Target Feed Rate After Dilution
50	0.5	3.2	6.4	0.32
100	1	6.4	12.9	0.63
200	1.9	12.9	25.7	1.26
300	2.9	19.3	38.6	1.89

TABLE 3 Gallons of Water Required to Dissolve One 25 Lb. Bag of Fertilizer

Target Fertilizer Concentration (ppm N) After Dilution	Injector Ratios 1:100	1:200
50	124.4	62.2
100	62.2	31.1
200	31.1	15.6
300	20.7	10.4

2. Determine your desired Target Fertilizer Concentration (ppm N) After Dilution.
3. Select your Injector Ratio Setting.
4. (a.)Table #2 - the value stated is the correct weight of fertilizer necessary to make one gallon of concentrate. (To Make More Than 1 Gallon: Multiply the value times the number of gallons of concentrate you wish to mix – i.e., stock tank volume.)
   (b.)Table #3 – the value stated is the volume (in gallons) of water required to dissolve one 25 pound bag of fertilizer.
5. Fill the concentrate tank to approximately 1/3 tank volume. (Note: if possible use warm water to more quickly dissolve the fertilizer.)
6. Add mineral acid only if necessary (addition may be required with alkalinity levels greater than 250 mg/L calcium carbonate).
7. Add fertilizer and stir vigorously.
8. Top off the tank volume with water.

Mixing For Watering Cans, Spray Tanks (No Injectors)

Conventional Measure	= Grams	+ Amount of water (gallons)	= ppm N
1 tsp	5.8	1	320
1 Tbsp	17.3	2	480
1 cup	276.7	25	614

100 gallons of water + 1 pound of fertilizer = 179.8 ppm N.

Product Properties

Potential Acidity	Conductivity of 100 ppm	Maximum Solubility
390 lbs. calcium carbonate equivalent per ton	0.63	4 lbs/gal

Fertilizer Compatibility – All Peters Excel fertilizers are tank mix compatible with each other. However, not all Peters Professional and Peters Excel water soluble fertilizer products are compatible. There can be problems when blending calcium containing fertilizers with sulfuric acid or sulfate containing fertilizers such as S.T.E.M.™, Epsom salts (magnesium sulfate). Refer to Everris Compatibility Information on our website.

Solubility – Product components are completely water soluble. However, a number of factors will determine how fast the fertilizer will dissolve (i.e., desired concentration, temperature of irrigation water, agitation, time, irrigation water quality, the fertilizer itself and compatibility of other components in the stock tank). Each product has a stated maximum solubility that is determined under ideal lab conditions – it is physically impossible to maintain solubility above this value.

Water Soluble Fertilizer Appearance – This product is composed from a number of components, varying in size. Some of the products are uniform in appearance while others quite heterogeneous. The tracer dye color intensity and distribution may appear variable in the bag. However, once the product is diluted in a stock tank the colorant level should be consistent.

Monitoring – The Everris Testing Laboratory is a reliable source for testing water, growing media or tissue. Injector monitoring and maintenance will help to ensure that you are feeding at optimal levels. Weekly on-site measurements of fertilizer solution and crop media EC and pH can be a valuable tool in managing your crop. A follow-up program of complete media analysis (and tissue in problem-solving situations), should be initiated to optimize your nutritional program.

Need More Information – To fine-tune your fertilizer selection to your individual growing conditions, you can contact an experienced Everris horticultural professional or you can refer to the **www.PetersABC.com** website to access the Peters ABC Selection System™.

EP99150

Peters® Excel 21-5-20

Multi Purpose

(For Continuous Liquid Feed Programs)

Guaranteed Analysis	F1877
Total nitrogen (N)	21%
7.3% ammoniacal nitrogen	
12.6% nitrate nitrogen	
1.1% urea nitrogen	
Available Phosphate (P_2O_5)	5%
Soluble potash (K_2O)	20%
Boron (B)	0.0262%
Copper (Cu)	0.0262%
0.0262% water soluble copper (Cu)	
Iron (Fe)	0.1050%
0.1050% chelated iron (Fe)	
Manganese (Mn)	0.0525%
0.0525% water soluble manganese (Mn)	
Molybdenum (Mo)	0.0105%
Zinc (Zn)	0.0525%
0.0525% water soluble zinc (Zn)	

Derived from: ammonium nitrate, ammonium phosphate, potassium nitrate, urea phosphate, boric acid, copper sulfate, iron EDTA, manganese sulfate, ammonium molybdate, zinc sulfate

Information regarding the contents and levels of metals in this product is available on the internet at **http://www.aapfco.org/metals.htm**

WARNING: This fertilizer contains more than .001% molybdenum (Mo). The application of fertilizing materials containing molybdenum (Mo) may result in forage crops containing levels of molybdenum (Mo) which are toxic to ruminant animals.

SAFETY INSTRUCTIONS:
FOR SAFETY INSTRUCTIONS, REFER TO THE MATERIAL SAFETY DATA SHEET, OR CALL 1-800-492-8255 or 314-983-7500.

WARNING: May be harmful if swallowed or inhaled. May cause irritation.
- Avoid contact with eyes, skin and clothing.
- Avoid breathing dust.
- Wash thoroughly after handling.
- Do not swallow.

First Aid: In case of contact, immediately flush with plenty of water for at least 15 minutes. Call a physician; flush skin with water. Wash clothing before reuse.

Spills and Disposal: If spilled, absorb with an inert noncombustible material and remove for disposal. Dispose of all waste in accordance with applicable government regulations.

Storage: Opened bags should be sealed. Unsealed or partially used products may take on moisture from the atmosphere and may subsequently soften or harden in the bag. As long as bags are properly re-sealed, this should in no way diminish nutrient content of the fertilizer. Store product in a cool, dry environment.

FOR PROFESSIONAL USE ONLY. KEEP OUT OF REACH OF CHILDREN.

DISCLAIMER AND LIMITATION OF LIABILITY
IMPORTANT NOTICE FROM EVERRIS NA INC. ("Everris"). PLEASE READ BEFORE USE.

By using this product, user or buyer accepts the conditions, disclaimer of warranties and limitations of liability. Read the entire directions for use, conditions of warranties and limitations of liability before using this product. If terms are not acceptable, return the unopened product container at once for full refund.

CONDITIONS: This product has been researched to provide necessary data to support its uses listed on the label. The directions for use of this product are believed to be adequate and the user or buyer must always follow the label directions carefully and exercise judgment and caution when using this product under their growing conditions. However, it is impossible to eliminate all risks associated with the use of this product. Crop injury, ineffectiveness, unsatisfactory or substandard results or other unintended consequences may result because of such factors as weather conditions, presence or absence of other materials, or the manner of use or application, all of which are beyond the control of Everris. All such risks shall be assumed by the user or buyer.

WARRANTY: This product corresponds to all claims and descriptions set forth on the label and, subject to the conditions set forth above, is reasonably fit for use for any purpose for which it is intended. Everris recognizes that the rights and remedies of the user or buyer are subject to the provisions of the applicable state law, but makes no other warranties or representations, express or implied, of merchantability or of fitness for a particular purpose or otherwise, that extend beyond the statements made on this label. No agent of Everris is authorized to make any warranties beyond those contained herein or to modify the warranties contained therein. Subject to the user's or buyer's rights and remedies under the applicable state law, Everris disclaims any liability whatsoever for special, incidental or consequential damages resulting from the use or handling of this product.

LIMITATIONS OF LIABILITY: Subject to the user's or buyer's rights and remedies under the applicable state law, the exclusive remedy of the user or buyer and the liability of Everris or its affiliates, for any and all losses, injuries or damages resulting from the use or handling of this product, whether in contract, warranty, tort, negligence, strict liability or otherwise, shall not exceed the purchase price paid by the user or buyer for the quantity of this product involved or at Everris' election, the replacement of the product. Subject to the user's or buyer's rights and remedies under the applicable state law, any and all claims or actions related to the use or handling of this product must be commenced within one (1) year from the date the product was purchased.

To request additional information, please contact your Everris Distributor or call Everris Customer Service at 1-800-492-8255 or 314-983-7500.

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Everris NA Inc.
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Dublin, OH 43016
Testing Lab: 1-877-467-8522

Made in the U.S.A.

050112

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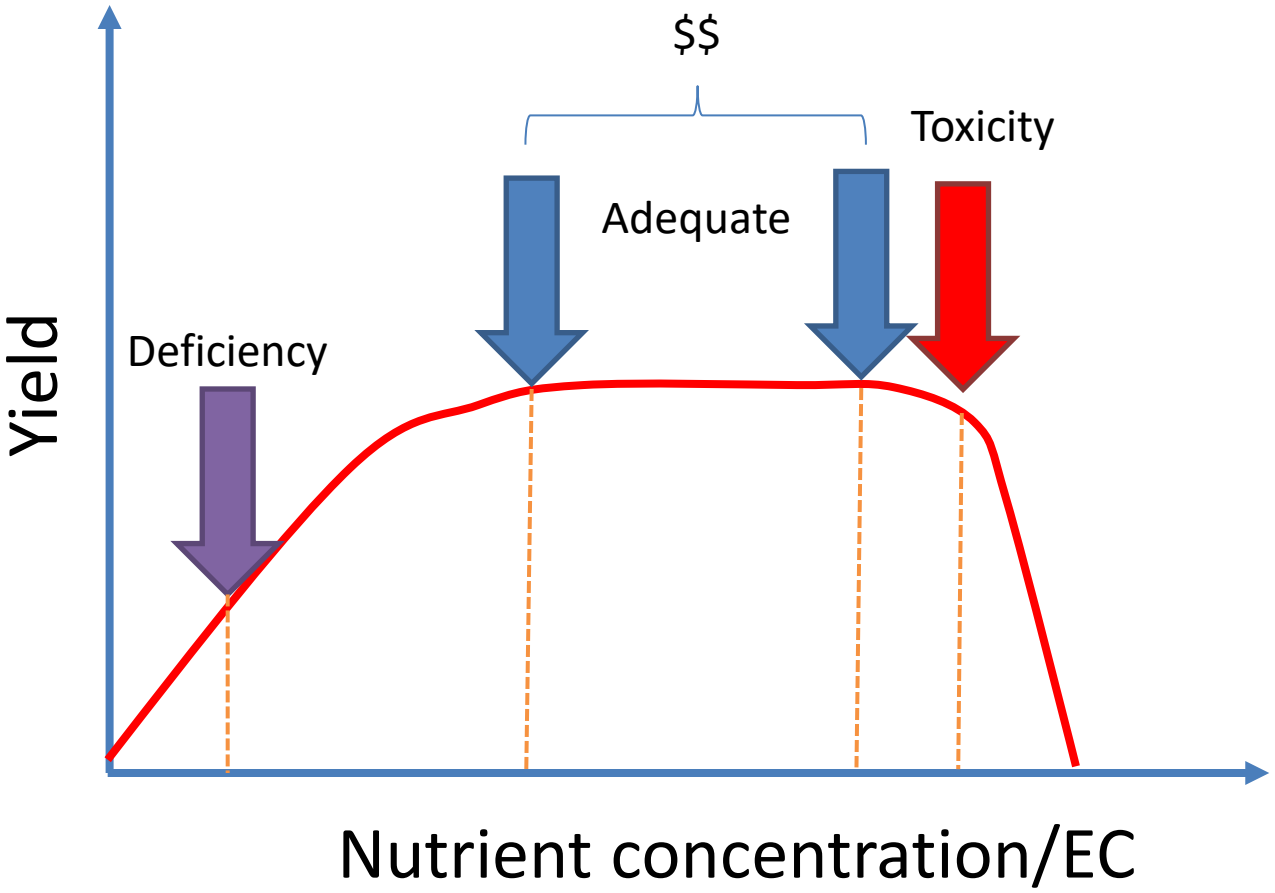
100	1	6.4	12.9	0.63
200	1.9	12.9	25.7	1.26
300	2.9	19.3	38.6	1.89

More is not better



Dissolved oxygen

Keep the water cool for healthy root systems

Adequate over 6 ppm

Dissolved oxygen

- Oxygen (O_2): Necessary respiration for root growth and nutrient uptake.
- Low O_2: inhibits growth, increases ethylene production.
- Optimum level for hydroponics over 6 ppm

Temperature affects how much oxygen is held by water

↑ Temperature=↓ oxygen solubility

°F	Temperature-Oxygen Solubility Relationship	
	Temperature (°C)	Oxygen Solubility (mg/L)
32	0	14.6
	5	12.8
	10	11.3
59	15	10.2
	20	9.2
77	25	8.6
	100	0

The solution temperature can affect plant health directly and indirectly.

Alkalinity

How often you need to adjust pH?

How easy it will be to change the pH?

Adequate 40 – 160 ppm

What is alkalinity?

- Alkalinity is a measure of the acid neutralizing capacity of water.
  - Bicarbonates (HCO_3^-): Ca, Mg, Na
  - Carbonates (CO_3^{--}): Ca, Mg, Na
  - Ions: hydroxides, phosphates, silicates, sulfides, and borates
- Think of it as “dissolved limestone”
- High alkalinity (>160 ppm)=higher amounts of acid needed to change the pH.
- Low alkalinity (<40 ppm)=pH changes constantly and you need to monitor and adjust pH constantly

How to measure alkalinity

- Equivalents of calcium carbonate ($CaCO_3$ ppm):
  - 1meq/L=50mg/L(ppm)=61mg/L HCO_3^-
- It is measured through titration.
- It can't be determined directly with a pH meter
- High pH ≠ high alkalinity

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  - pH
  - Electrical conductivity
  - Dissolved oxygen
  - Alkalinity
- Nutrient requirements
- Making nutrient solutions
- Monitoring nutrient solutions
- Plant production timeline and steps
- Common problems

Crop nutrient requirements

Remember to give the proper amounts

Specific crop and growth stage requirements

- Given as part per million (ppm), %, or milligrams per liter (mg/L).

1 ppm: 1/1,000,000

Liquids: 1 mg/L (1milligram in 1 liter)

Solids: 1 mg/kg (1 milligram in 1 kilogram)

1%: 1/100 = 10,000 ppm

- Recommendations for hydroponic nutrient solutions given as ppm of elements

Requirements by crop and growth stage (ppm N)

Type	Propagation	Production
Buttercrunch/Boston Bibb	125	150
Romaine, Red and Green leaf	125	150
Basil	125	175
Culinary Herbs	125	150
Cole Crops	125	175
Garlic and Scallions	125	150
Tomatoes	125	200
Peppers	125	150
Cucumber	125	175
Heavy Feeders cabbage, kale, spinach, Swiss chard, mustard greens, mizuna, escarole	125	175 - 200
Light Feeder Lettuce arugula, watercress, spring mix	125	125 - 150

Fertilizer recipe: Lettuce

Target recommendation

	16-4-17 (1 bag)	5-11-26+ $CaNO_3$ (2 bag)	9-7-37+ $CaNO_3$ + $MgSO_4$ (3 bag)	Sonneveld's Solution
Nitrogen (ppm)	150	150	150	150
Phosphorus (ppm)	16	39	12	31
Potassium (ppm)	132	162	122	210
Calcium (ppm)	38	139	133	90
Magnesium (ppm)	14	47	42	24
Iron (ppm)	2.1	2.3	2.0	1.0
Manganese(ppm)	0.47	0.38	0.75	0.25
Zinc (ppm)	0.49	0.11	0.75	0.13
Boron (ppm)	0.21	0.38	0.36	0.16
Copper (ppm)	0.13	0.11	0.20	0.02
Molybdenum (ppm)	0.08	0.08	0.04	0.02

Strawberry media and fertility

- Use media mixes with good draining capacity
- Drain 20-30% of the irrigation water
- 6-12 irrigation events (200-400 mL per plant per day)
- High nitrogen fertilization triggers vegetative growth. Strawberries prefer 5-10% of total N from ammonium

Hydroponic strawberry nutrient requirements

Element	Yamazaki/Jack's	Tochigi	Chem-Gro™
NO_3-N	70	111	102
NH_4-N	7	10	3.6
P	15	30	12
K	117	156	120
Ca	40	86	85
Mg	12	22	30
S	(16)	11	--
Micronutrient	Ranges for berry formulations		
Fe (Chelated)	2 - 3	Cu	0.02 – 0.5
B	0.3 – 0.8	Mo	0.02 – 0.08
Mn	0.55 – 1.5	Zn	0.03 – 0.33

Unit: ppm or mg/L

For every 10 L add*

- 5 g of 8-10-26
- 2.5 g of 15-0-0
- 1.5 g of Epsom salts

**Based on deionized water. Contact your extension specialist for a recipe that matches your water source.*

- Jack's two bag system: 8-10-26 + 15-0-0

Source: Kubota and Kroggel OSU

Vine crop requirements

(ppm)	Tomato	Cucumber
N	125-225	160-210
NH_4 (% Total N)	5-10	7-14
P	40-60	40-60
K	200-350	325-370
Ca	120-180	190-210
S	40-140	120-140
Mg	30-60	60-75
Fe	3-7	1-2
K/N Proportion	1:1 to 1.7:1	1.8:1 to2.1:1
EC	1.5-3.5	1.5-3.0

Courtesy: Richard McAvoy, Univ. of Connecticut

Tomato nutrient requirement by growth stage

Growth stage	K:N
Vegetative stage (before first flower)	1:1
1st to 4th cluster	1.5:1
Ripe fruit	1.7:1

To promote vegetative growth in any stage by increasing the amount of ammonium nitrogen (NH_4).

Courtesy: Richard McAvoy Univ. of Connecticut

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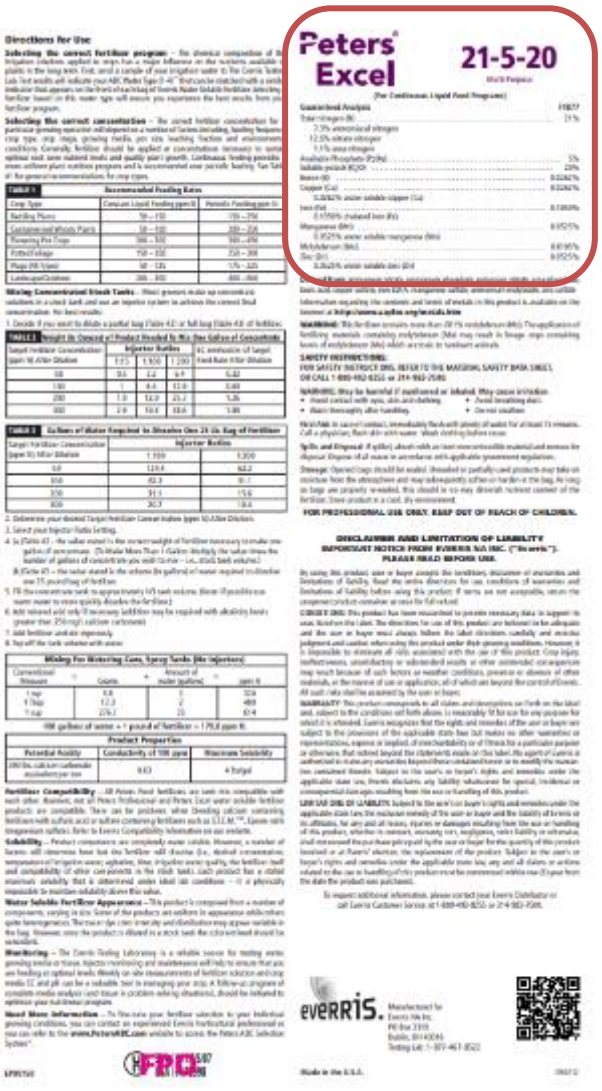
READING FERTILIZER LABELS

- Water soluble
- Single or multiple bag product?
- Dye
- Elements provided
- Expected EC
- Nitrogen composition
  - Acidity or basicity potential



Peters® Excel 21-5-20 Multi Purpose

(For Continuous Liquid Feed Programs)

Guaranteed Analysis	F1877
Total nitrogen (N)	21%
7.3% ammoniacal nitrogen	
12.6% nitrate nitrogen	
1.1% urea nitrogen	
Available Phosphate (P_2O_5)	5%
Soluble potash (K_2O)	20%
Boron (B)	0.0262%
Copper (Cu)	0.0262%
0.0262% water soluble copper (Cu)	
Iron (Fe)	0.1050%
0.1050% chelated iron (Fe)	
Manganese (Mn)	0.0525%
0.0525% water soluble manganese (Mn)	
Molybdenum (Mo)	0.0105%
Zinc (Zn)	0.0525%
0.0525% water soluble zinc (Zn)	

N%

P_2O_5 %

K_2O %

Directions for Use

Selecting the correct fertilizer program – The chemical composition of the irrigation solutions applied to crops has a major influence on the nutrients available to plants in the long term. First, send a sample of your irrigation water to The Everris Testing Lab. Test results will indicate your ABC Water Type (1-4)™ that can be matched with a similar indicator that appears on the front of each bag of Everris Water Soluble Fertilizer. Selecting a fertilizer based on this water type will ensure you experience the best results from your fertilizer program.

Selecting the correct concentration – The correct fertilizer concentration for a particular growing operation will depend on a number of factors including, feeding frequency, crop type, crop stage, growing media, pot size, leaching fraction and environmental conditions. Generally, fertilizer should be applied at concentrations necessary to sustain optimal root zone nutrient levels and quality plant growth. Continuous feeding provides a more uniform plant nutrition program and is recommended over periodic feeding. See Table #1 for general recommendations for crop types.

TABLE 1 Recommended Feeding Rates

Crop Type	Constant Liquid Feeding ppm N	Periodic Feeding ppm N
Bedding Plants	50 – 150	150 – 250
Containerized Woody Plants	50 – 100	200 – 350
Flowering Pot Crops	200 – 300	300 – 450
Potted Foliage	150 – 200	250 – 300
Plugs (All Types)	50 – 125	175 – 225
Landscape/Outdoors	200 – 300	400 – 600

Mixing Concentrated Stock Tanks – Most growers make up concentrate solutions in a stock tank and use an injector system to achieve the correct final concentration. For best results:

TABLE 2 Weight (In Ounces) of Product Needed To Mix One Gallon of Concentrate

Target Fertilizer Concentration (ppm N) After Dilution	Injector Ratios 1:15	1:100	1:200	EC mmhos/cm of Target Feed Rate After Dilution
50	0.5	3.2	6.4	0.32
100	1	6.4	12.9	0.63
200	1.9	12.9	25.7	1.26
300	2.9	19.3	38.6	1.89

TABLE 3 Gallons of Water Required to Dissolve One 25 Lb. Bag of Fertilizer

Target Fertilizer Concentration (ppm N) After Dilution	Injector Ratios 1:100	1:200
50	124.4	62.2
100	62.2	31.1
200	31.1	15.6
300	20.7	10.4

2. Determine your desired Target Fertilizer Concentration (ppm N) After Dilution.
3. Select your Injector Ratio Setting.
4. (a.)Table #2 - the value stated is the correct weight of fertilizer necessary to make one gallon of concentrate. (To Make More Than 1 Gallon: Multiply the value times the number of gallons of concentrate you wish to mix – i.e., stock tank volume.)
   (b.)Table #3 – the value stated is the volume (in gallons) of water required to dissolve one 25 pound bag of fertilizer.
5. Fill the concentrate tank to approximately 1/3 tank volume. (Note: if possible use warm water to more quickly dissolve the fertilizer.)
6. Add mineral acid only if necessary (addition may be required with alkalinity levels greater than 250 mg/L calcium carbonate).
7. Add fertilizer and stir vigorously.
8. Top off the tank volume with water.

Mixing For Watering Cans, Spray Tanks (No Injectors)

Conventional Measure	= Grams	+ Amount of water (gallons)	= ppm N
1 tsp	5.8	1	320
1 Tbsp	17.3	2	480
1 cup	276.7	25	614

100 gallons of water + 1 pound of fertilizer = 179.8 ppm N.

Product Properties

Potential Acidity	Conductivity of 100 ppm	Maximum Solubility
390 lbs. calcium carbonate equivalent per ton	0.63	4 lbs/gal

Fertilizer Compatibility – All Peters Excel fertilizers are tank mix compatible with each other. However, not all Peters Professional and Peters Excel water soluble fertilizer products are compatible. There can be problems when blending calcium containing fertilizers with sulfuric acid or sulfate containing fertilizers such as S.T.E.M.™, Epsom salts (magnesium sulfate). Refer to Everris Compatibility Information on our website.

Solubility – Product components are completely water soluble. However, a number of factors will determine how fast the fertilizer will dissolve (i.e., desired concentration, temperature of irrigation water, agitation, time, irrigation water quality, the fertilizer itself and compatibility of other components in the stock tank). Each product has a stated maximum solubility that is determined under ideal lab conditions – it is physically impossible to maintain solubility above this value.

Water Soluble Fertilizer Appearance – This product is composed from a number of components, varying in size. Some of the products are uniform in appearance while others quite heterogeneous. The tracer dye color intensity and distribution may appear variable in the bag. However, once the product is diluted in a stock tank the colorant level should be consistent.

Monitoring – The Everris Testing Laboratory is a reliable source for testing water, growing media or tissue. Injector monitoring and maintenance will help to ensure that you are feeding at optimal levels. Weekly on-site measurements of fertilizer solution and crop media EC and pH can be a valuable tool in managing your crop. A follow-up program of complete media analysis (and tissue in problem-solving situations), should be initiated to optimize your nutritional program.

Need More Information – To fine-tune your fertilizer selection to your individual growing conditions, you can contact an experienced Everris horticultural professional or you can refer to the **www.PetersABC.com** website to access the Peters ABC Selection System™.

EP99150

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0.0525% water soluble manganese (Mn)	
Molybdenum (Mo)	0.0105%
Zinc (Zn)	0.0525%
0.0525% water soluble zinc (Zn)	

Derived from: ammonium nitrate, ammonium phosphate, potassium nitrate, urea phosphate, boric acid, copper sulfate, iron EDTA, manganese sulfate, ammonium molybdate, zinc sulfate

Information regarding the contents and levels of metals in this product is available on the internet at **http://www.aapfco.org/metals.htm**

WARNING: This fertilizer contains more than .001% molybdenum (Mo). The application of fertilizing materials containing molybdenum (Mo) may result in forage crops containing levels of molybdenum (Mo) which are toxic to ruminant animals.

SAFETY INSTRUCTIONS:
FOR SAFETY INSTRUCTIONS, REFER TO THE MATERIAL SAFETY DATA SHEET, OR CALL 1-800-492-8255 or 314-983-7500.

WARNING: May be harmful if swallowed or inhaled. May cause irritation.
- Avoid contact with eyes, skin and clothing.
- Avoid breathing dust.
- Wash thoroughly after handling.
- Do not swallow.

First Aid: In case of contact, immediately flush with plenty of water for at least 15 minutes. Call a physician; flush skin with water. Wash clothing before reuse.

Spills and Disposal: If spilled, absorb with an inert noncombustible material and remove for disposal. Dispose of all waste in accordance with applicable government regulations.

Storage: Opened bags should be sealed. Unsealed or partially used products may take on moisture from the atmosphere and may subsequently soften or harden in the bag. As long as bags are properly re-sealed, this should in no way diminish nutrient content of the fertilizer. Store product in a cool, dry environment.

FOR PROFESSIONAL USE ONLY. KEEP OUT OF REACH OF CHILDREN.

DISCLAIMER AND LIMITATION OF LIABILITY
IMPORTANT NOTICE FROM EVERRIS NA INC. ("Everris"). PLEASE READ BEFORE USE.

By using this product, user or buyer accepts the conditions, disclaimer of warranties and limitations of liability. Read the entire directions for use, conditions of warranties and limitations of liability before using this product. If terms are not acceptable, return the unopened product container at once for full refund.

CONDITIONS: This product has been researched to provide necessary data to support its uses listed on the label. The directions for use of this product are believed to be adequate and the user or buyer must always follow the label directions carefully and exercise judgment and caution when using this product under their growing conditions. However, it is impossible to eliminate all risks associated with the use of this product. Crop injury, ineffectiveness, unsatisfactory or substandard results or other unintended consequences may result because of such factors as weather conditions, presence or absence of other materials, or the manner of use or application, all of which are beyond the control of Everris. All such risks shall be assumed by the user or buyer.

WARRANTY: This product corresponds to all claims and descriptions set forth on the label and, subject to the conditions set forth above, is reasonably fit for use for any purpose for which it is intended. Everris recognizes that the rights and remedies of the user or buyer are subject to the provisions of the applicable state law, but makes no other warranties or representations, express or implied, of merchantability or of fitness for a particular purpose or otherwise, that extend beyond the statements made on this label. No agent of Everris is authorized to make any warranties beyond those contained herein or to modify the warranties contained therein. Subject to the user's or buyer's rights and remedies under the applicable state law, Everris disclaims any liability whatsoever for special, incidental or consequential damages resulting from the use or handling of this product.

LIMITATIONS OF LIABILITY: Subject to the user's or buyer's rights and remedies under the applicable state law, the exclusive remedy of the user or buyer and the liability of Everris or its affiliates, for any and all losses, injuries or damages resulting from the use or handling of this product, whether in contract, warranty, tort, negligence, strict liability or otherwise, shall not exceed the purchase price paid by the user or buyer for the quantity of this product involved or at Everris' election, the replacement of the product. Subject to the user's or buyer's rights and remedies under the applicable state law, any and all claims or actions related to the use or handling of this product must be commenced within one (1) year from the date the product was purchased.

To request additional information, please contact your Everris Distributor or call Everris Customer Service at 1-800-492-8255 or 314-983-7500.

everris.

Manufactured for
Everris NA Inc.
PO Box 3310
Dublin, OH 43016
Testing Lab: 1-877-467-8522

Made in the U.S.A.

050112

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200	1.9	12.9	25.7	1.26
300	2.9	19.3	38.6	1.89

Fertilizer calculations (1 bag)

Example: Prepare 10 liters (L) of nutrient solution with 100 ppm N using the 21-5-20 fertilizer

- *Remember 100 ppm N = 100 mg N in 1 L of solution
- 21-5-20 : %N-%P_2O_5-%K_2O

- **Step 1**. Calculate how much nitrogen you need for your nutrient solution tank.

For 10 L we need : 10 L X 100 ppm N= 1,000 mg N

ALWAYS USE WATER SOLUBLE FERTILIZERS

Check the handout for the two fertilizer bags calculations

Fertilizer calculations (1 bag)

- **Step 2.** Calculate how much fertilizer you need to meet your nitrogen needs (1,000 mg N from step 1)

$$F = NR \div (\%N \div 100)$$

F: required fertilizer, *NR:* required nitrogen (step 1),

%N: percent nitrogen in the fertilizer (label)

$F = 1{,}000\ mg\ N \div (21 \div 100)$ =4,762 mg or 4.7 g in 10 L of water

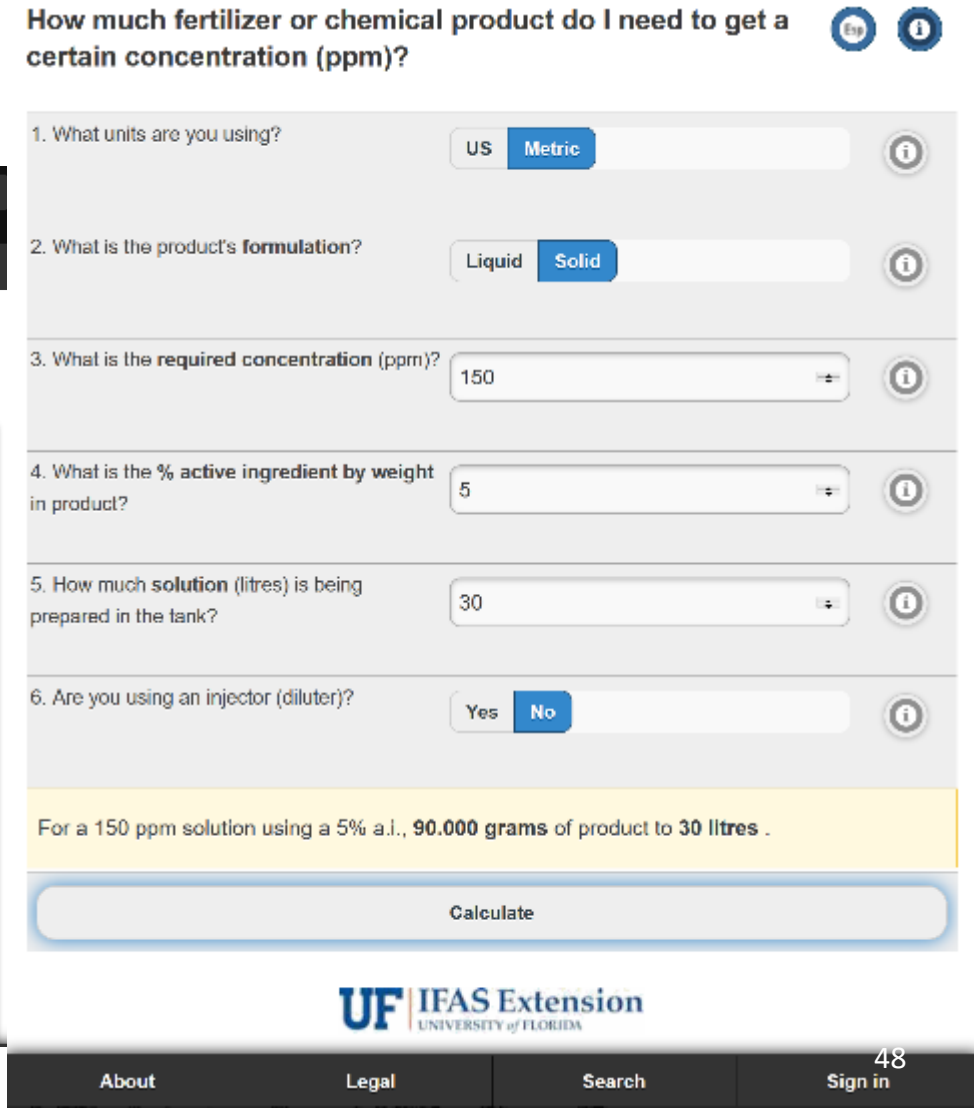
To convert grams (g) to ounces: gram x 0.035274

To convert liters (L) to gallons US: liters x 0.26417

https://scienceinhydroponics.com/

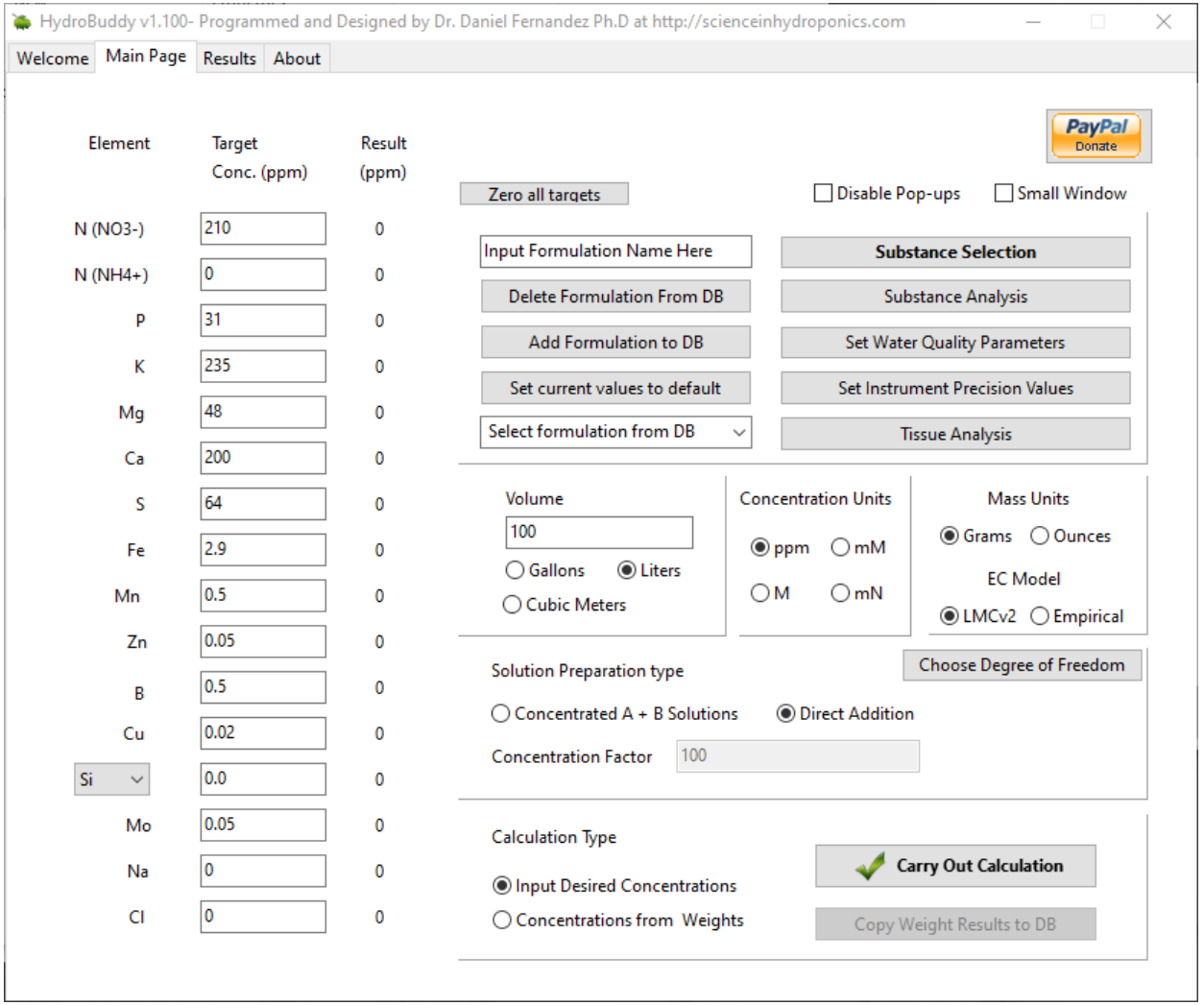
Online calculators

https://www.backpocketgrower.org/calculators.asp



Online calculators

https://scienceinhydroponics.com/2016/03/the-first-free-hydroponic-nutrient-calculator-program-o.html



Basil

- For every 10 gallons add*:
  - 1.5 oz (42.5 grams) of 5-12-26
  - 0.8 oz (22.7 grams) of 15.5-0-0
- Dilute fertilizers separately
- Measure pH and EC
- Adjust pH to 5.8 to 6.2

Element	Plant requirement ppm	Provided by recipe
Total N	150	151
P	63	138
K	302	299
Ca	92	114
Mg	49	69
S	53	98
B	0.4	0.6
Cu	0.2	0.2
Fe	2.5	3.5
Mn	0.5	0.6
Mo	0.06	0.22
Zn	0.3	0.2

**Based on deionized water. Contact your extension specialist for a recipe that matches your water source.*

Lettuce

- For every 10 gallons add*
  - 1.34 oz (40 grams) of 5-12-26 fertilizer
  - 0.87 oz (25 grams) of 15.5-0-0 fertilizer
- Dilute the fertilizers separately each in 5 gallons then combine the dissolved fertilizers
- Measure pH and EC
- Adjust the pH between 5.5 to 6.0

Element	Plant requirement ppm	Provided by recipe
Total N	150	150.75
P	31	110
K	210	260
Ca	90	123.5
Mg	24	31
S	0	40
B	0.16	0.5
Cu	0.02	0.15
Fe	1	3
Mn	0.25	0.5
Mo	0.02	0.1
Zn	0.13	0.15

**Based on deionized water. Contact your extension specialist for a recipe that matches your water source.*

Hydroponic strawberry nutrient requirements

Element	Yamazaki/Jack's	Tochigi	Chem-Gro™
NO_3-N	70	111	102
NH_4-N	7	10	3.6
P	15	30	12
K	117	156	120
Ca	40	86	85
Mg	12	22	30
S	(16)	11	--
Micronutrient	Ranges for berry formulations		
Fe (Chelated)	2 - 3	Cu	0.02 – 0.5
B	0.3 – 0.8	Mo	0.02 – 0.08
Mn	0.55 – 1.5	Zn	0.03 – 0.33

Unit: ppm or mg/L

For every 10 L add

- 5 g of 8-10-26
- 2.5 g of 15-0-0
- 1.5 g of Epsom salts

- Jack's two bag system: 8-10-26 + 15-0-0

Source: Kubota and Kroggel OSU

Tomato Stage 1

- Use until you see the first cluster of flowers (approx. 6 weeks)
- For every 10 gallons add*:
  - 0.8 oz (23 grams) of 5-12-26
  - 1 oz (29 grams) of 15.5-0-0
  - 0.4 oz (11 grams) of Epsom salts
- Dilute fertilizers separately
- Measure pH and EC
- Adjust pH 5.5 to 6.5

Element	Plant requirement ppm	Provided by recipe
Total N	145	150
P	47	72
K	145	156
Ca	144	147
Mg	60	65
S	10	90
B	0.4	0.30
Cu	0.05	0.09
Fe	2	2
Mn	0.55	0.30
Mo	0.05	0.11
Zn	0.33	0.09
K:N ratio	1.0	1.04

**Based on deionized water. Contact your extension specialist for a recipe that matches your water source.*

Tomato Stage 2

- Use until you see the fourth cluster of flowers (weeks 6 to 12)
- For every 10 gallons add*:
  - 1.5 oz (43 grams) of 5-12-26
  - 1.2 oz (34 grams) of 15.5-0-0
- Dilute fertilizers separately
- Measure pH and EC
- Adjust pH to 5.5 to 6.5

Element	Plant requirement ppm	Provided by recipe
Total N	195	195
P	47	137
K	300	300
Ca	160	168
Mg	60	69
S	10	98
B	0.4	0.58
Cu	0.05	0.17
Fe	2	3. 5
Mn	0.55	0.58
Mo	0.05	0.22
Zn	0.33	0.17
K:N ratio	1.54	1.54

**Based on deionized water. Contact your extension specialist for a recipe that matches your water source.*

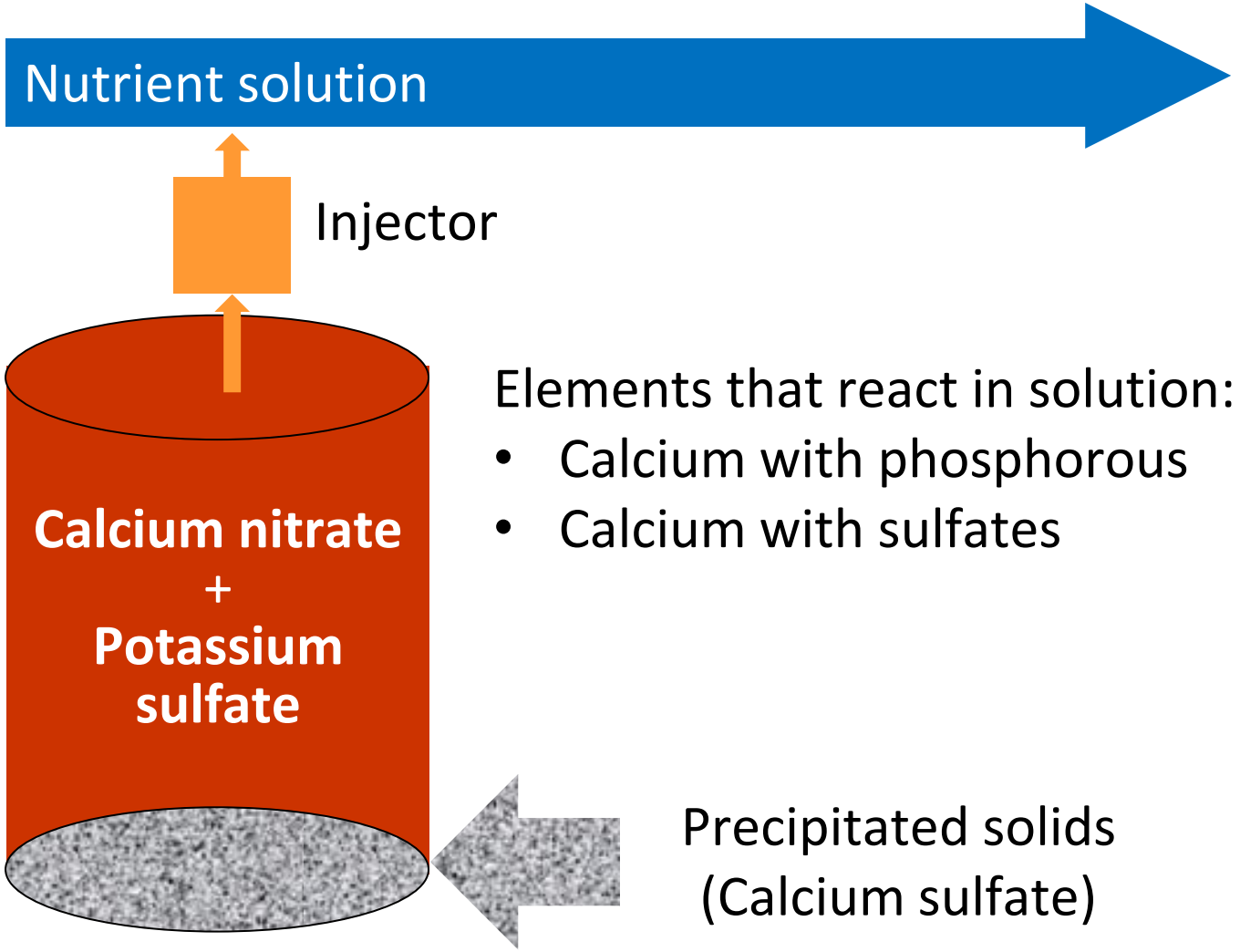
Tomato Stage 3

- Use when you see the fruits ripening (plants older than 12 weeks)
- For every 10 gallons add*:
  - 2 oz (57 grams) of 5-12-26
  - 1.4 oz (39 grams) of 15.5-0-0
- Dilute fertilizers separately
- Measure pH and EC
- Adjust pH 5.5 to 6.5

Element	Plant requirement ppm	Provided by recipe
Total N	205	240
P	47	186
K	350	403
Ca	200	200
Mg	60	93
S	10	132
B	0.4	0.8
Cu	0.05	0.2
Fe	2	4.7
Mn	0.55	0.8
Mo	0.05	0.3
Zn	0.33	0.2
K:N ratio	1.7	1.68

**Based on deionized water. Contact your extension specialist for a recipe that matches your water source.*

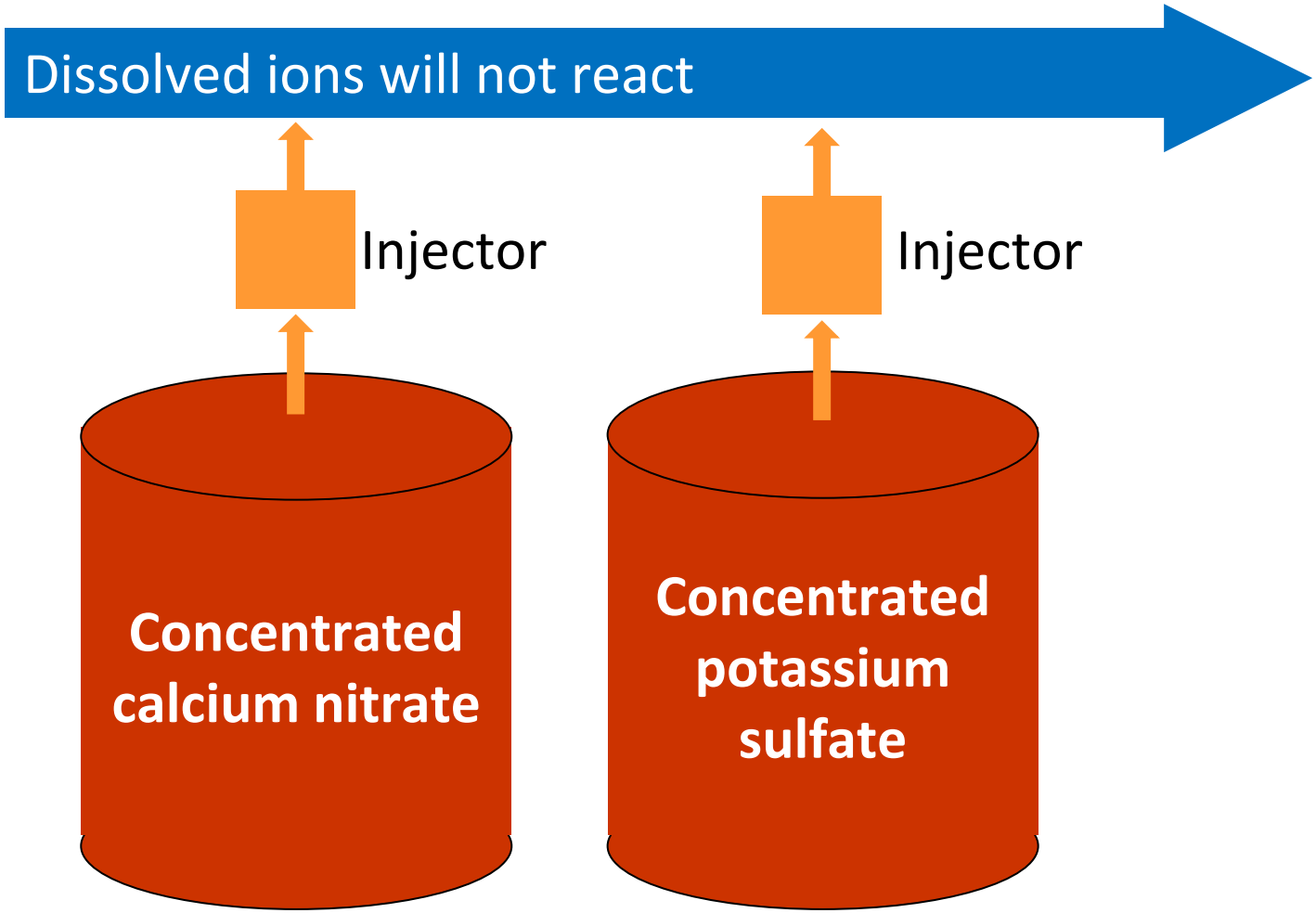
Fertilizer Incompatibility: Salt reaction



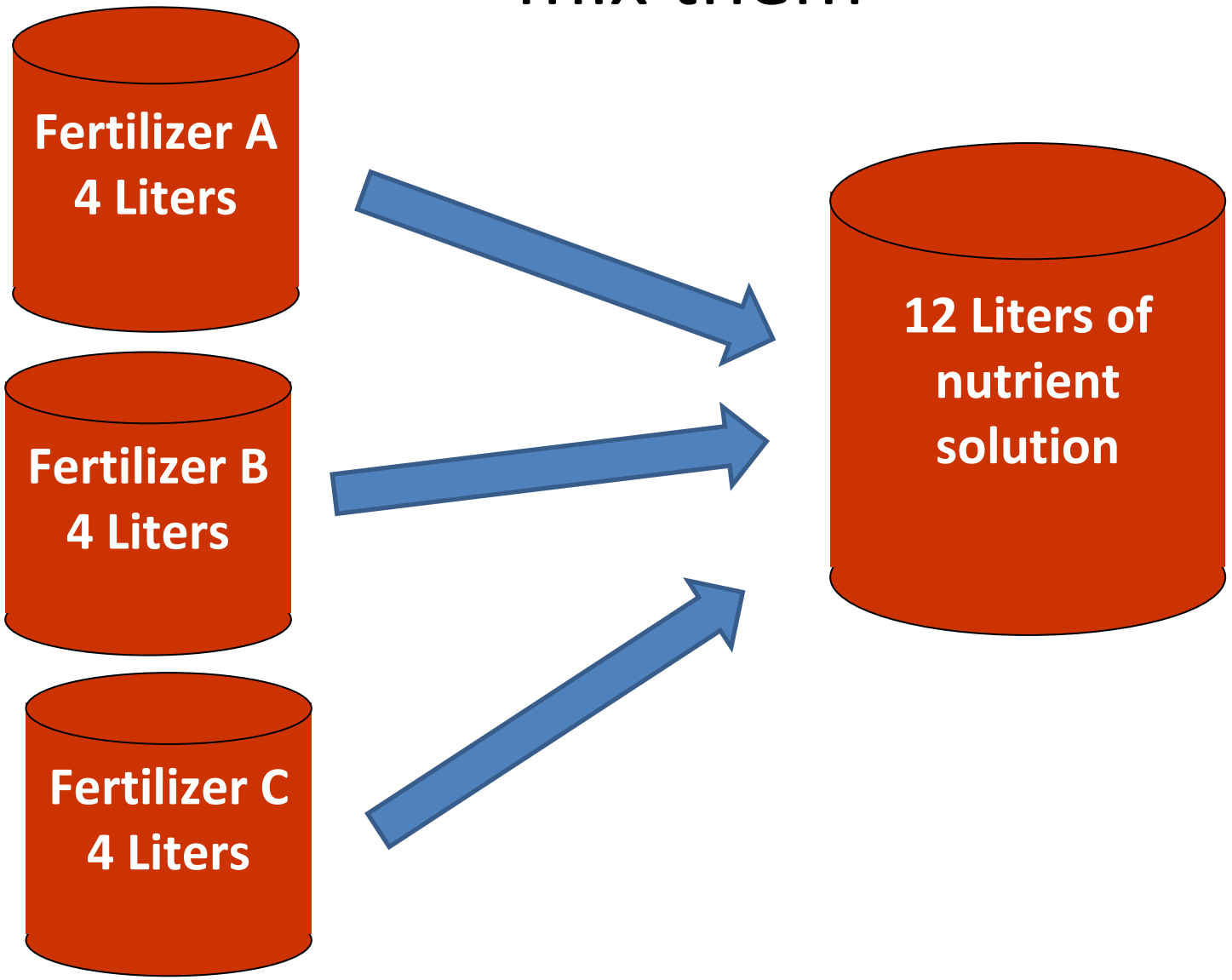
Elements that react in solution:

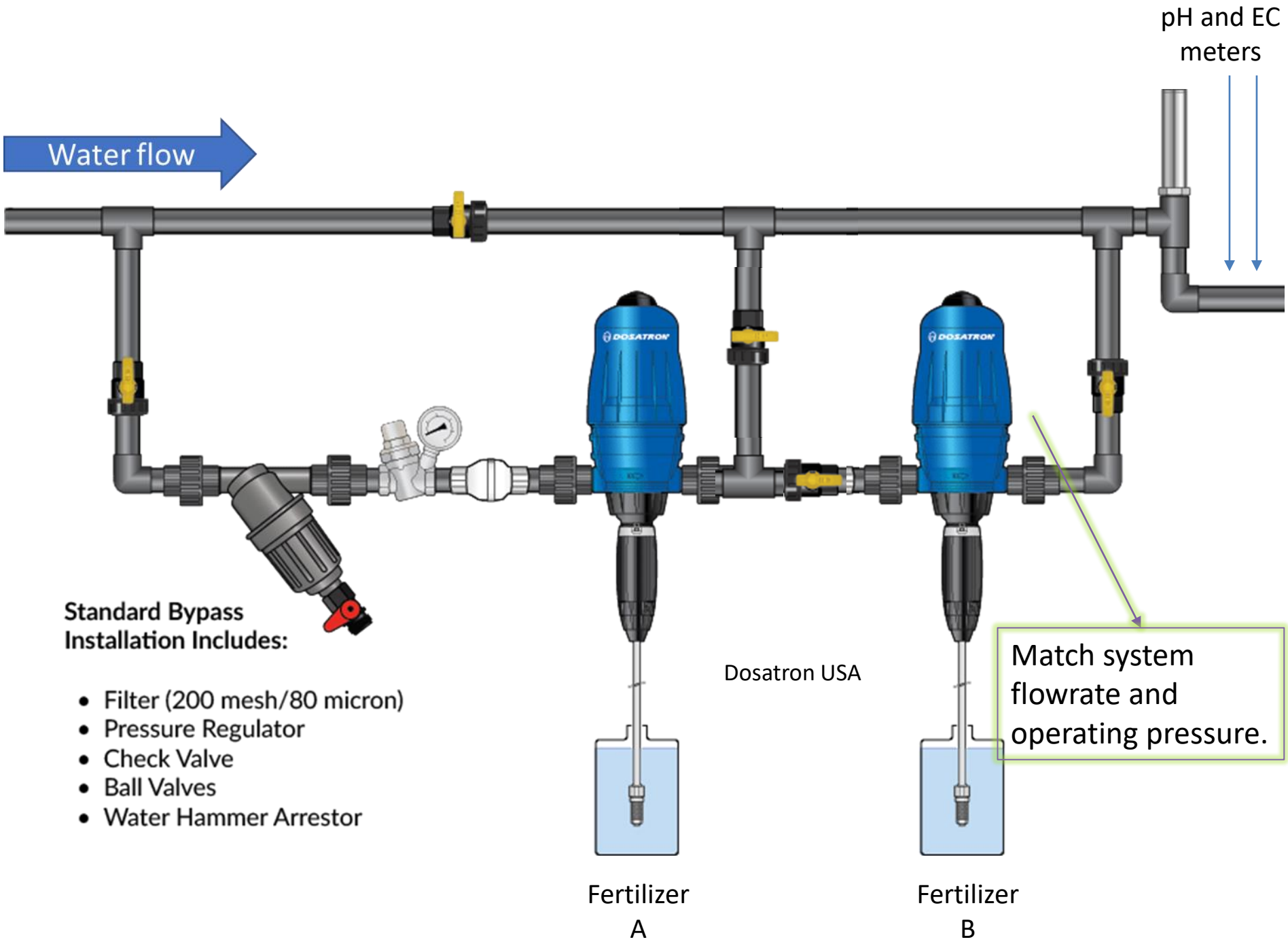
- Calcium with phosphorous
- Calcium with sulfates

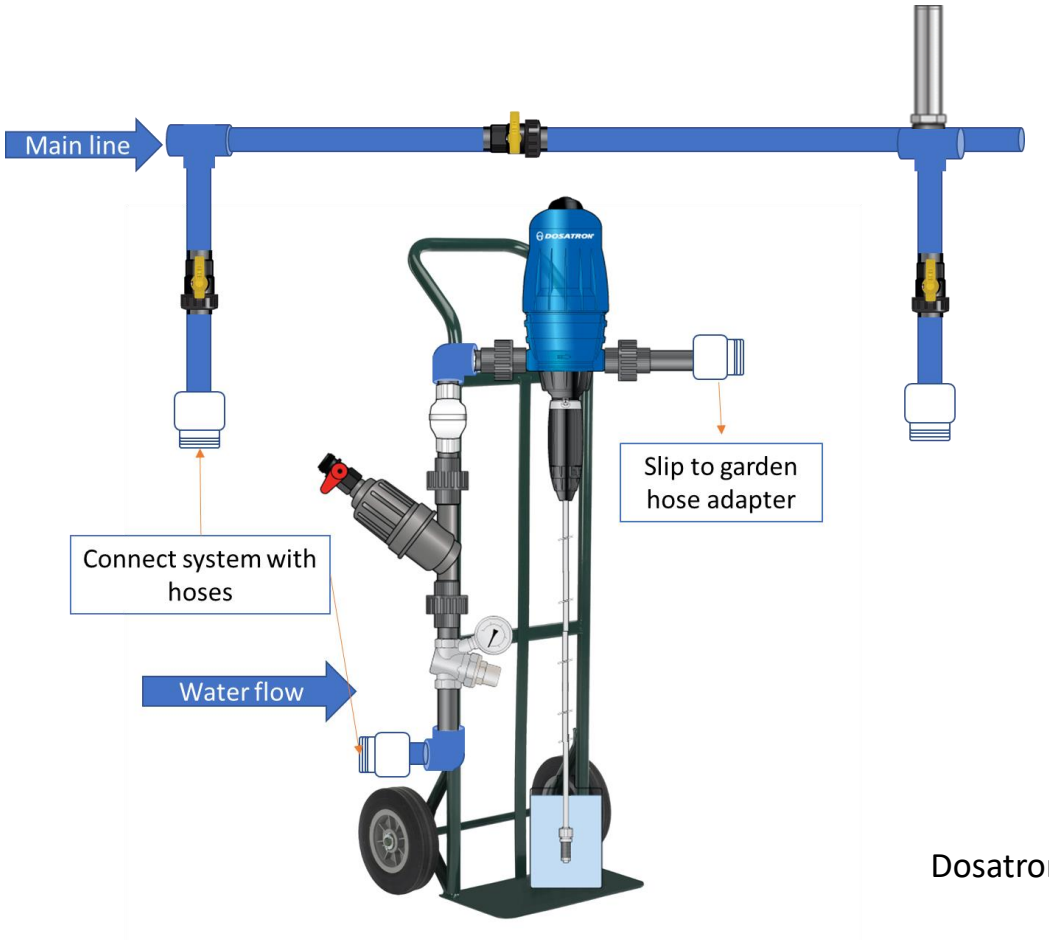
Option 1: Separate incompatible salts in different concentrated tanks



Dissolve fertilizers separately then mix them




pH and EC meters
Water flow
DOSATRON
DOSATRON
Standard Bypass Installation Includes:
• Filter (200 mesh/80 micron)
• Pressure Regulator
• Check Valve
• Ball Valves
• Water Hammer Arrestor
Dosatron USA
Match system flowrate and operating pressure.
Fertilizer A
Fertilizer B



Dosatron USA

Nutrient solution management

1. Test your water source.
2. Research nutrient requirements for your crops (nutrient levels and pH).
3. Calculate how much fertilizer you need for the nutrient solutions.
4. Prepare nutrient solutions.
5. Measure pH and EC.
6. Adjust the pH as needed.
7. Constantly measure and adjust the pH and EC of the nutrient solution.

Topics

- Nutrient solutions definitions
  - pH
  - Electrical conductivity
  - Dissolved oxygen
  - Alkalinity
- Nutrient requirements
- Making nutrient solutions
- Monitoring nutrient solutions
- Plant production timeline and steps
- Common problems

Why monitor and adjust nutrient solutions?

- The pH and EC of the nutrient solution changes after mixing the fertilizers. We need to know how it changes so we can adjust it to the plants' comfort zone.
- Over time, plants and microbes use water and nutrients which generate changes to pH and EC of the nutrient solution.
- We need to constantly monitor the nutrient solution to make necessary adjustments.
- **KEEP THE PLANTS IN THEIR COMFORT ZONE SO THEY CAN GROW!**

The pH of the nutrient solution may fluctuate every day and it is necessary to control it.

Increasing the pH

- Use:
  - Potassium bicarbonate
  - Fertilizers with high nitrate concentration (less than 25% of the total nitrogen from ammonium/urea)
  - Potassium hydroxide
- Avoid using calcium carbonate (lime) because it has low solubility.

Lowering the pH

Chemical	Notes
Mineral and organic acids	Cost $$: Citric /Acetic> Phosphoric > Nitric> Sulfuric Safety: Citric > Phosphoric ≈ Sulfuric > Nitric Consider that some will provide additional nutrients.

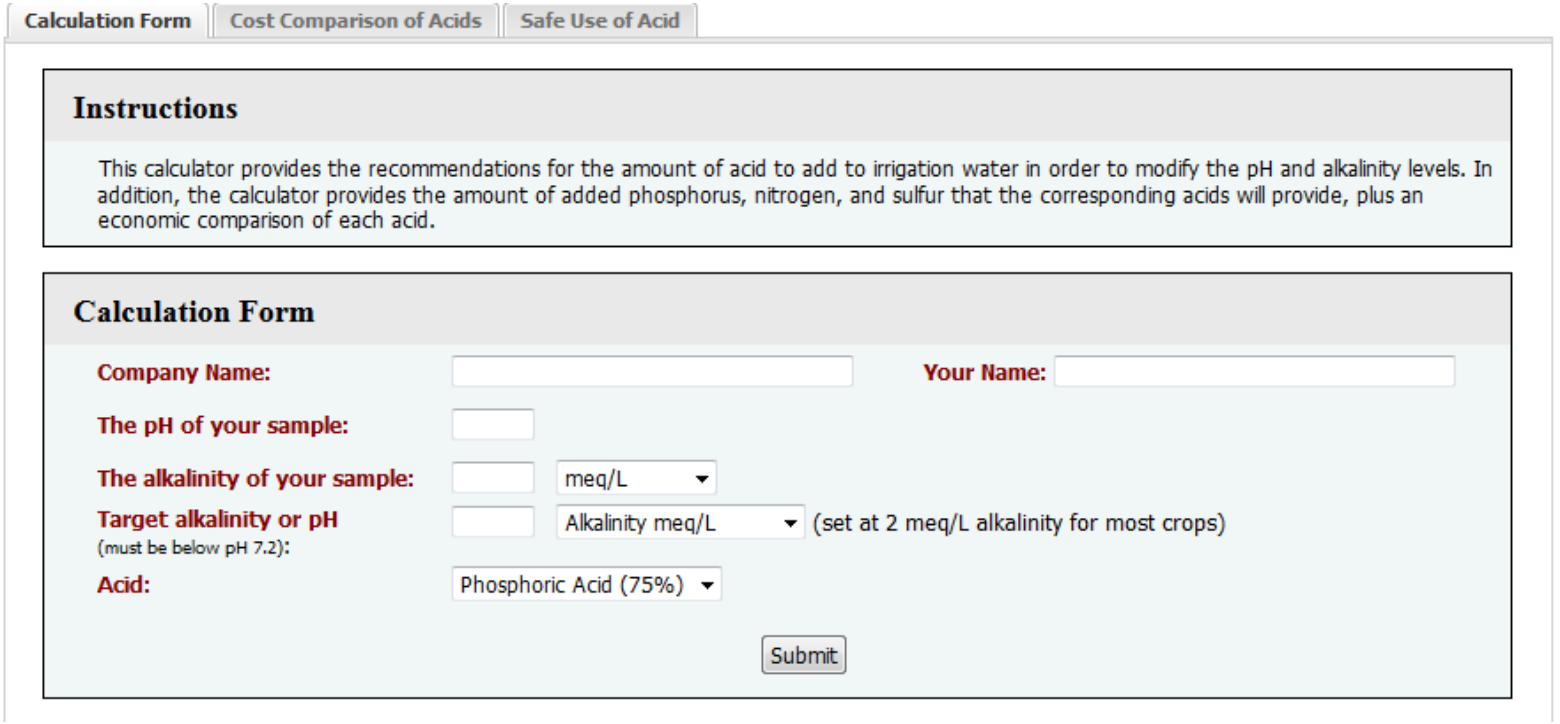
How much acid you need?
Depends on the alkalinity
of the nutrient solution.

How much acid you need?

- Online calculator:

e-Gro Alkalinity Calculator

http://e-gro.org/alkcalc/



Automatic injectors

Monitoring pH and EC

Monitoring pH and EC

- Cheap meters make inaccurate measurements that can result in costly mistakes
- A meter is as precise as the last time it was calibrated

Growing media pH

Perlite

Coir

Rockwool

Potting mix

Expanded clay pellets

What is the pH in the rootzone in organic media?

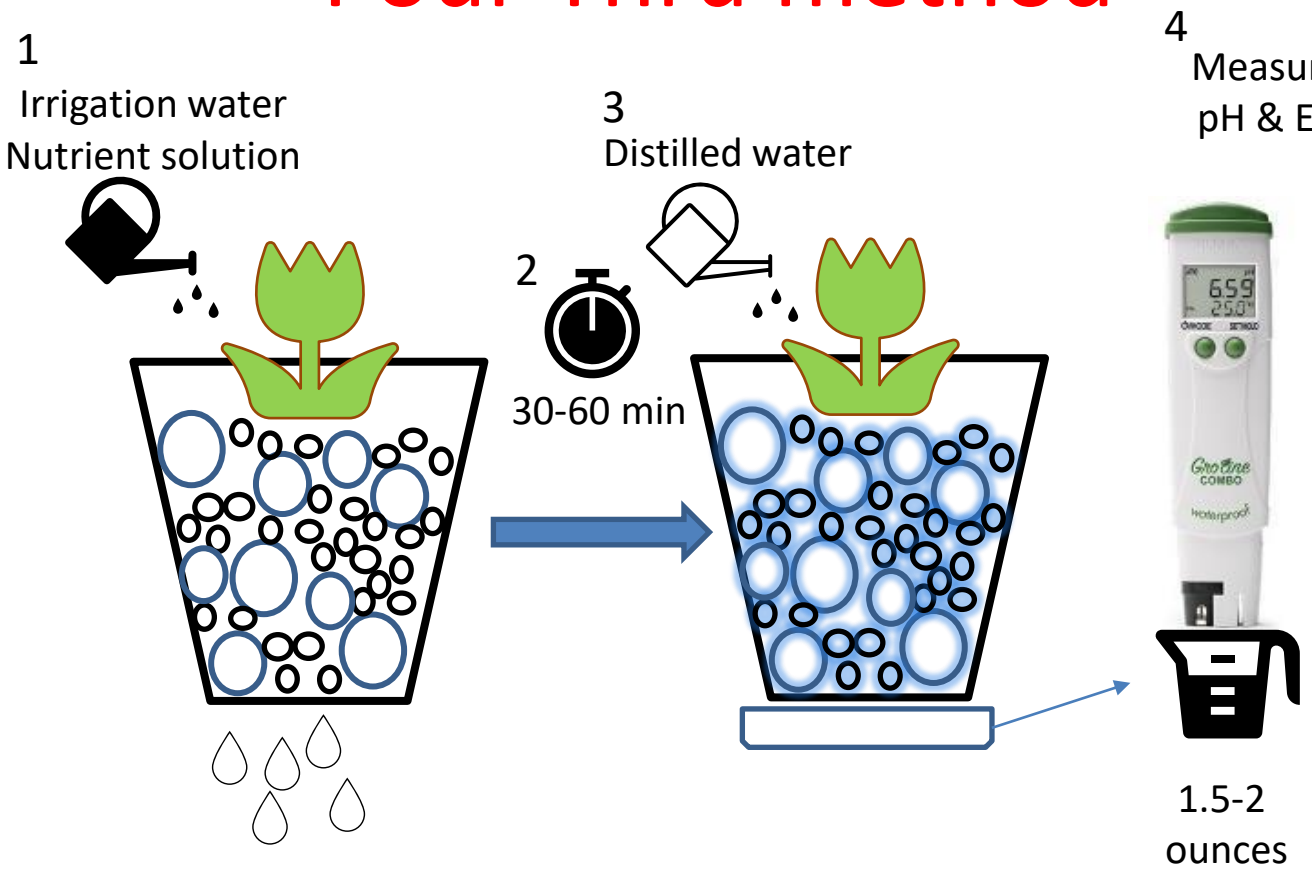
pH of nutrient solution ≠ rootzone pH

Gravel

Inert

pH of nutrient solution = rootzone pH

Root zone pH and EC monitoring – Pour Thru method



Pour Thru method not suitable for crops with sub irrigation

Inert materials: pH nutrient solution = pH of rootzone

Choosing meters

- Avoid test strips for pH (dyes in fertilizers).
- The ideal meter:
  - Water and shock proof
  - Replaceable probes
  - Easy to calibrate
  - Available calibrating and storage solutions
  - Portable
  - pH-EC Combo
  - $100-$300

Photos: Hannah instruments

Proper care for meters

Photo: Hannah instruments

- Calibrate once a week
  - Calibrate in two points: pH 4 and 7
- Do not touch, scratch or rub paper towel on the pH probe glass bulb
- Store the pH probe in **storage solution** or the pH 4 calibrating solution (not water)
- Rinse with distilled or deionized water before every use, after calibration, in between samples, and before storing
- Probe lifetime pH 1-2 years and EC 2-5 years
  - Replace when you can't calibrate

Meters needed

Combo meter

Parameter	Hydroponics	Aquaponics
pH	✓	✓
EC	✓	✓
Temperature	✓	✓
Dissolved oxygen	DWC only ✓	✓
Nitrate	⊘	✓
Nitrites	⊘	✓
Ammoniacal nitrogen	⊘	✓

Organic Fertilizers

3-1-1

GUARANTEED ANALYSIS

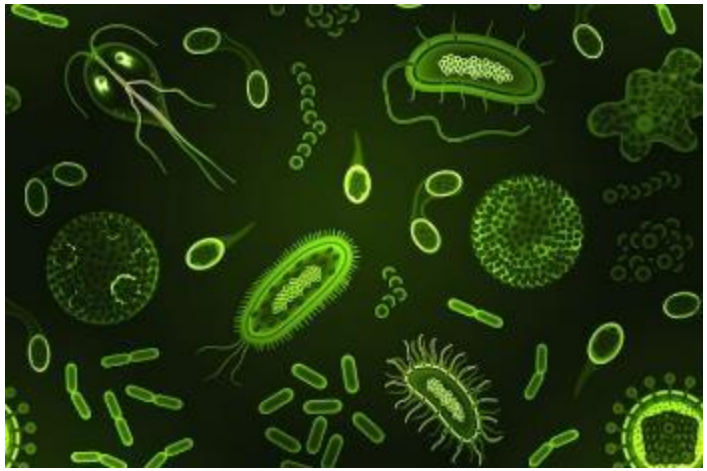
Total Nitrogen (N) 3%
2.55% Water Soluble Nitrogen
0.45% Water Insoluble Nitrogen

Available Phosphate (P_2O_5).....1%

Soluble Potash (K_2O) 1%

Derived From: Fermented Oilseed Extract

10 lbs. per gallon at 68°F **F2358**



Microbial activity needed:
develop biofilters and isolate key microorganisms

Organic fertilizers in hydroponics

- Currently, the effective use of organic fertilizers in hydroponics is unknown
  - Why? Organic fertilizers consists of organic matter, which plants are unable to break down without the assistance of microorganisms

Why use organic fertilizers?

- Using organic fertilizers allows farmers to obtain organic certification for their produce
- Organic certification may help hydroponic farmers increase their profit margins so they can sell their produce at higher market values

Photo: USDA

Our hypothesis

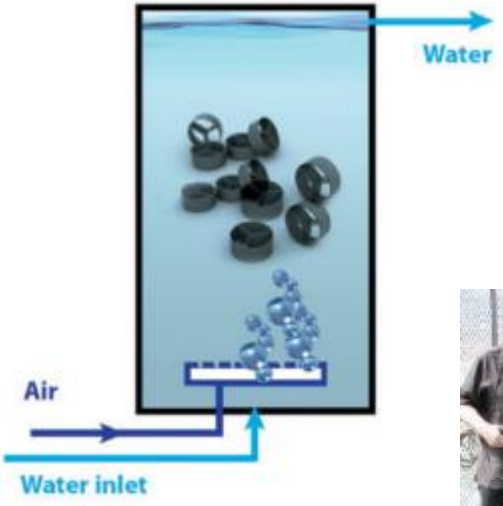
The addition of biofilters to a hydroponic system will allow microorganisms to break down the organic matter into viable nitrogen forms, which the plants can readily absorb

What is a Biofilter?

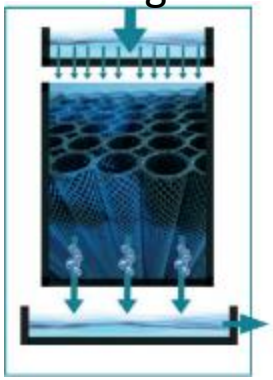
- A filter that hosts bacteria which can transform toxic forms of nitrogen to nitrate (safe for fish and plants)

Granular media

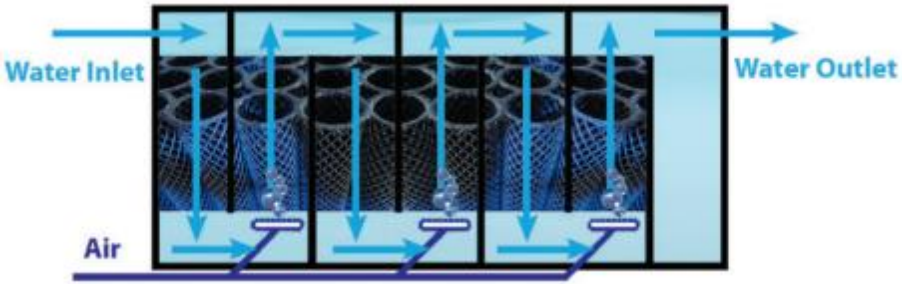
Moving bed biofilter



Trickling filter



Fixed bed biofilter



Objectives

1. Develop a biofilter prototype and optimize its operation to improve nutrient availability from organic fertilizers in hydroponics.
2. Determine if the addition of biofilters to a hydroponics system will enable the cultivation of healthy produce when using organic fertilizers.
3. Compare yields and resource use efficiency of conventional fertilizers with organic fertilizers in hydroponic lettuce cultivation.

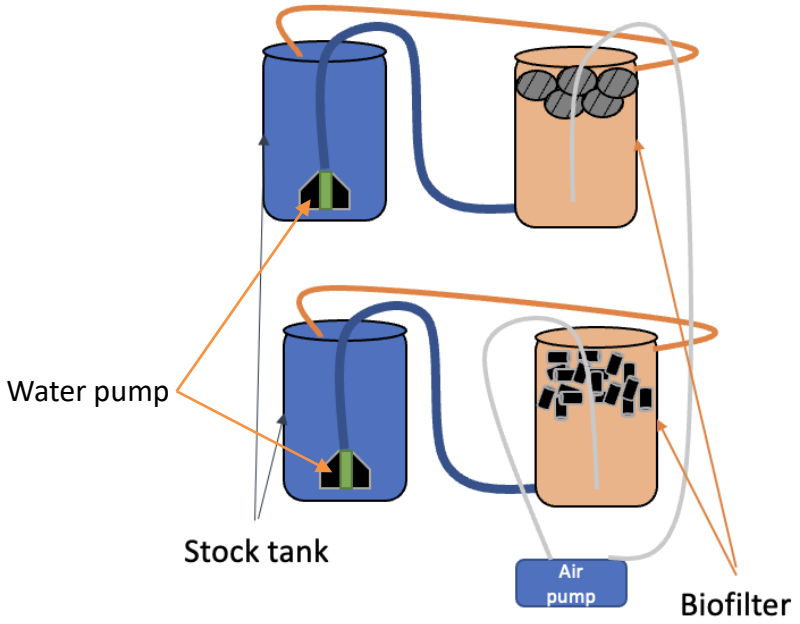
How are we testing this?

There are three phases to our experiment:

- Phase 1: Biofilter prototype build
- Phase 2: Biofilter priming ★
- Phase 3: Plant growth

Phase 1: Biofilter prototype build

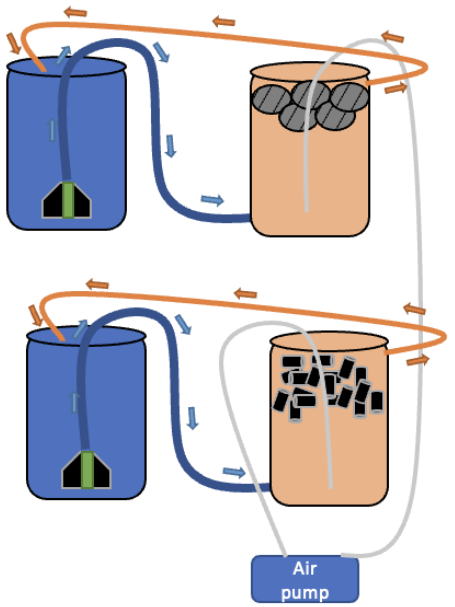
- Build two biofilters using charcoal or plastic media
- Determine the volume of solution the tanks can hold
- Calculate specific surface area of the media (SSA=SA/M)
- Fill stock tank with water and add the organic fertilizer: Multiply by the L of water in the tanks:
  - 1.1 g of 14-0-0
  - 1 g of langbeinite
  - 0.26 g of liquid bone meal
  - 1.4 g of liquid calcium



Biofilter prototype

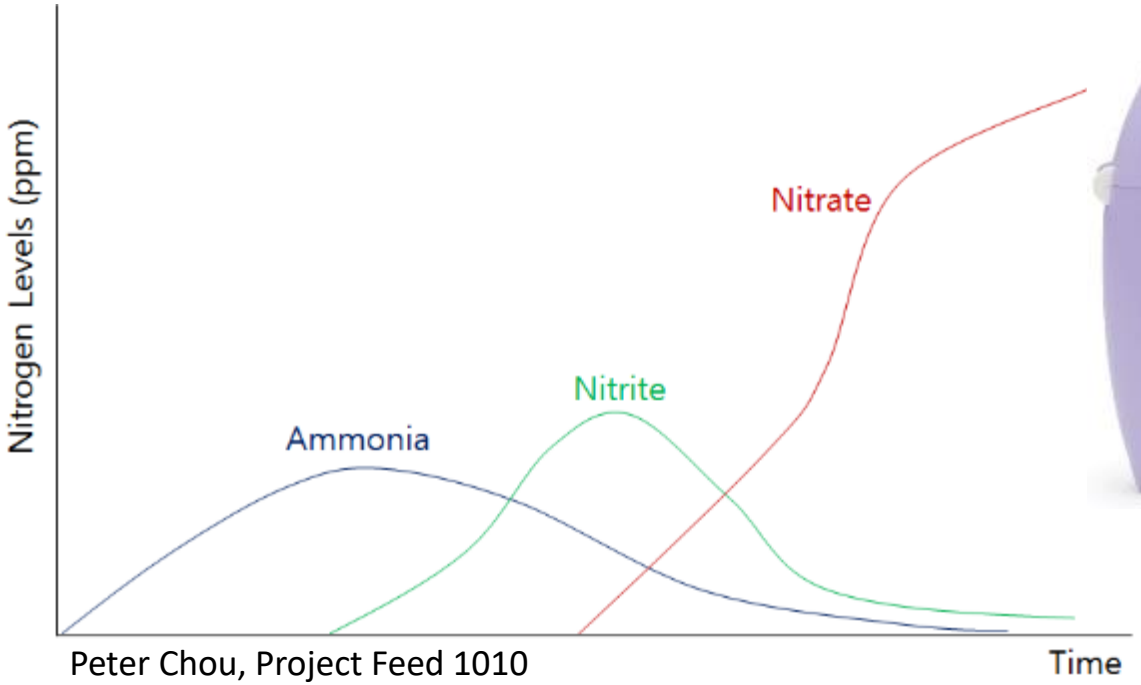
Phase 2: Biofilter priming ★

- Recirculate the organic fertilizer nutrient solution in the biofilter
- Make sure both filters have similar flow rates
  - Use flow meters
- Conduct daily/weekly measurements to ensure bacterial growth
  - Measure pH (adjust if needed), electrical conductivity (EC), temperature, dissolved oxygen (DO), and flow rate (same time every day), and smell
  - Measure ammonium, nitrite, and nitrate (every other day)
- Inspect for leaks
- Check water level
- Biofilter is primed when NH4<1ppm, NO2<1ppm, and NO3<150ppm



Priming the biofilters

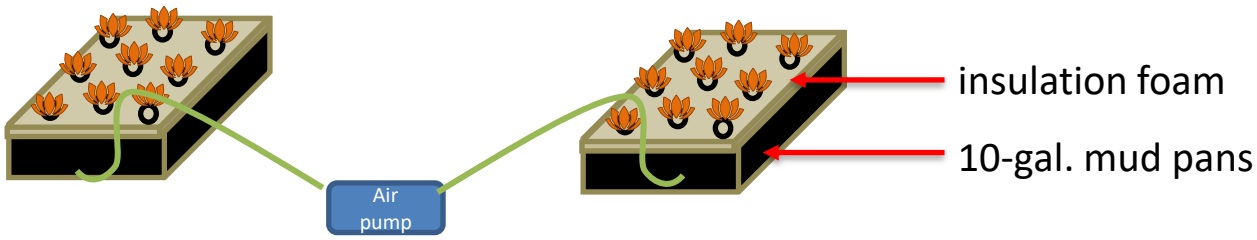
- Use colorimeters to know when the biofilter is ready
  - Ammonia and nitrites <1 ppm
  - Nitrate <150 ppm



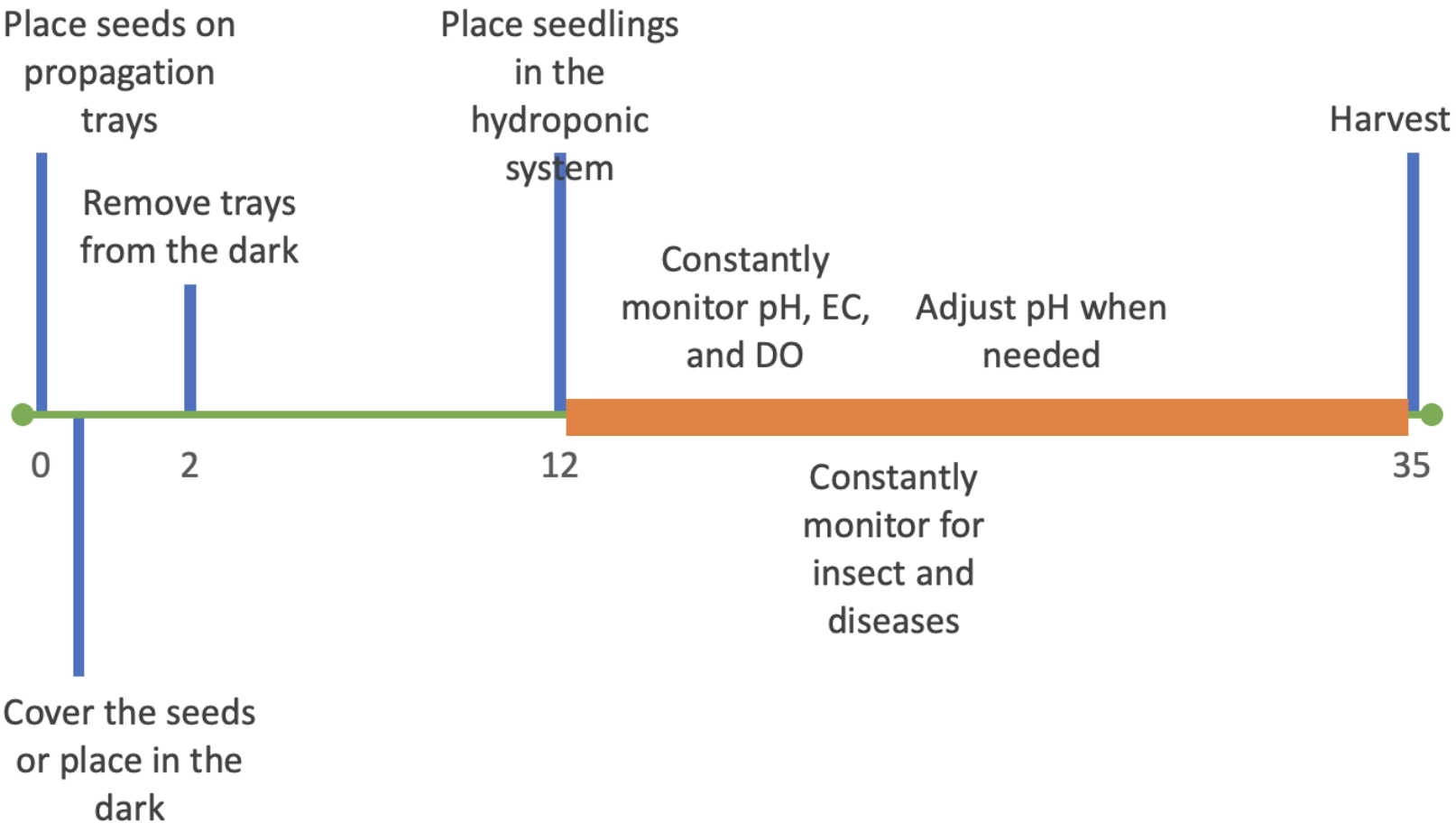
Peter Chou, Project Feed 1010

Phase 3: Plant Growth

- Compare plant growth using the following solutions:
  - Conventional fertilizer (control group)
    - For each L add 0.9 g of 5-12-26 and 0.7 g of 15-0-0
  - Organic fertilizer solution (same recipe used to prime biofilters)
  - Solution coming from plastic bead biofilter
  - Solution coming from charcoal biofilter
- 18 plants for each nutrient solution



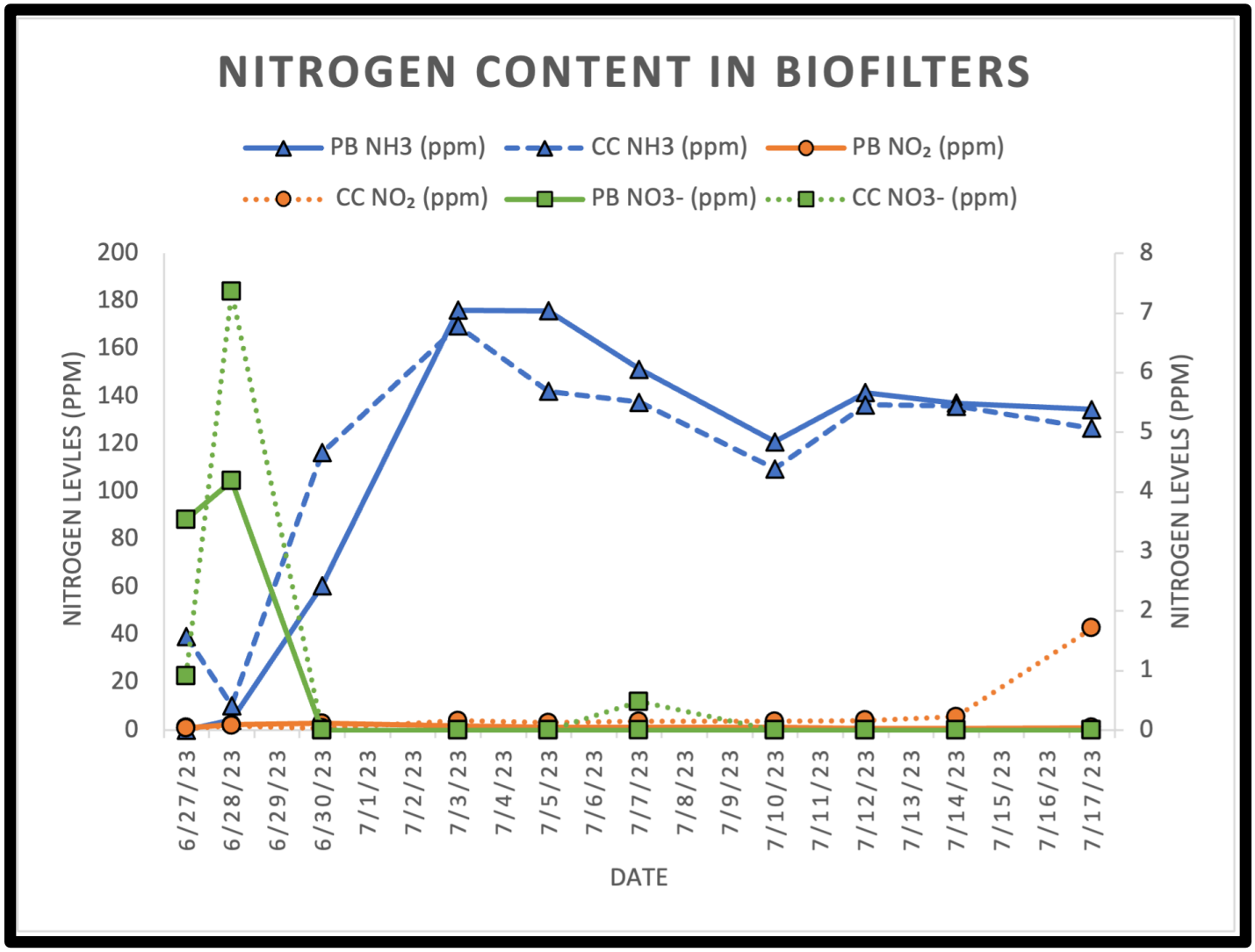
Hydroponic lettuce production timeline



Phase 3: Plant Growth pt. 2

- Take daily measurements of solution pH, EC, DO, and temperature to ensure proper growing environment
- Take weekly measurements of ammonium, nitrite, nitrate, plant diameter, plant height, and plant chlorophyll (SPAD meter)
- At harvest, root weight, root length, shoot weight (fresh and dry), plant chlorophyll, and tissue samples will be tested and measured for a full data analysis of the plant's growth

Current data



Work in progress…

- We are currently waiting for the biofilters to be finished priming
- Although this study is still a work in progress, we hope to discover that the incorporation of biofilters in hydroponics when using organic fertilizers will permit the growth of healthy produce as efficiently, or better than, using salt-based conventional fertilizers

Topics

- Nutrient solutions definitions
  - pH
  - Electrical conductivity
  - Dissolved oxygen
  - Alkalinity
- Nutrient requirements
- Making nutrient solutions
- Monitoring nutrient solutions
- Plant production timeline and steps
- Common problems

Media for seedling production

Rockwool

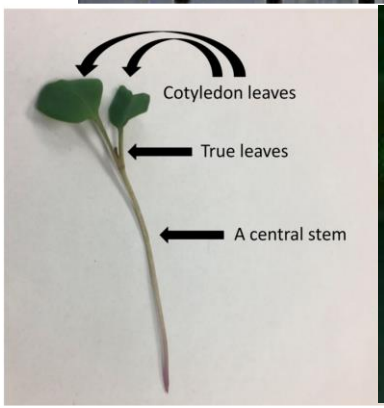
Compressed peat or coconut coir pellets

Synthetic materials

Foto: Grodan.com

Seedling production

1. Saturate the media with water (no fertilizers)
2. Place the seeds on the media
3. Cover the seeds for 24-48 hours (or place in a dark room)
4. Remove the cover and place seeds under light and keep them moist using a 75 ppm N nutrient solution
5. Seedlings will be ready when the first pair of true leaves are **fully expanded**
6. Place the seedling in the system on the net pots



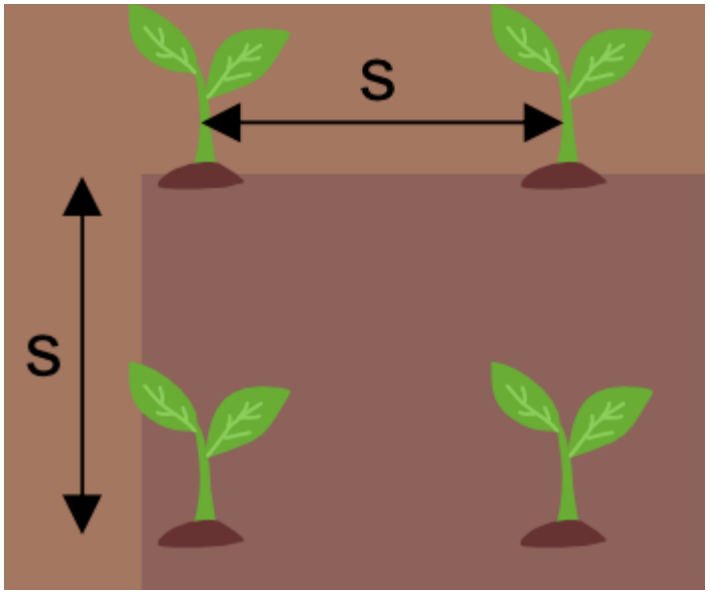
System prep before transplant

- Clean debris from previous crop
- Inspect system for leaks and broken parts
- Make sure you have all meters and materials in stock
  - Fertilizers
  - Acid and base (adjust pH)
  - Conductivity and pH meters (with calibrating solutions)
  - Air pumps with air diffusers (DWC system)
- Mix fertilizer with water then adjust pH

Plant spacing (greens/herbs)

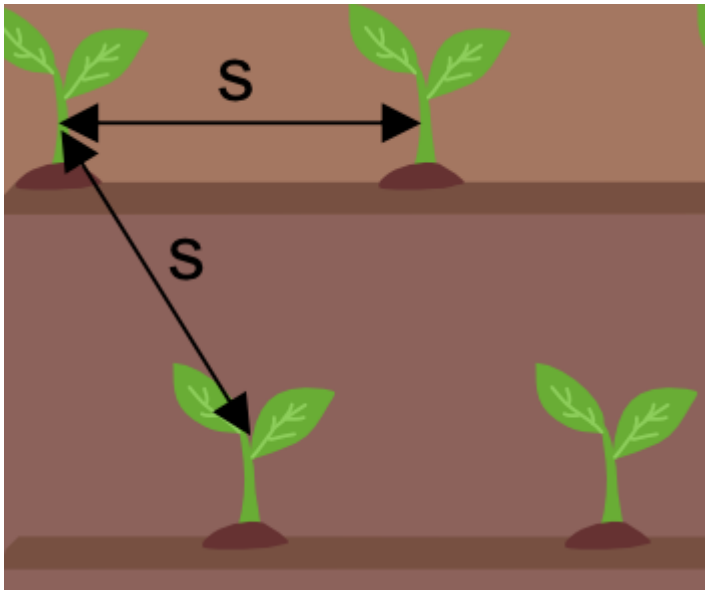
Square

- Plant distance: 8”
- Row distance: 8”
- Plants in 100 sq ft: 210



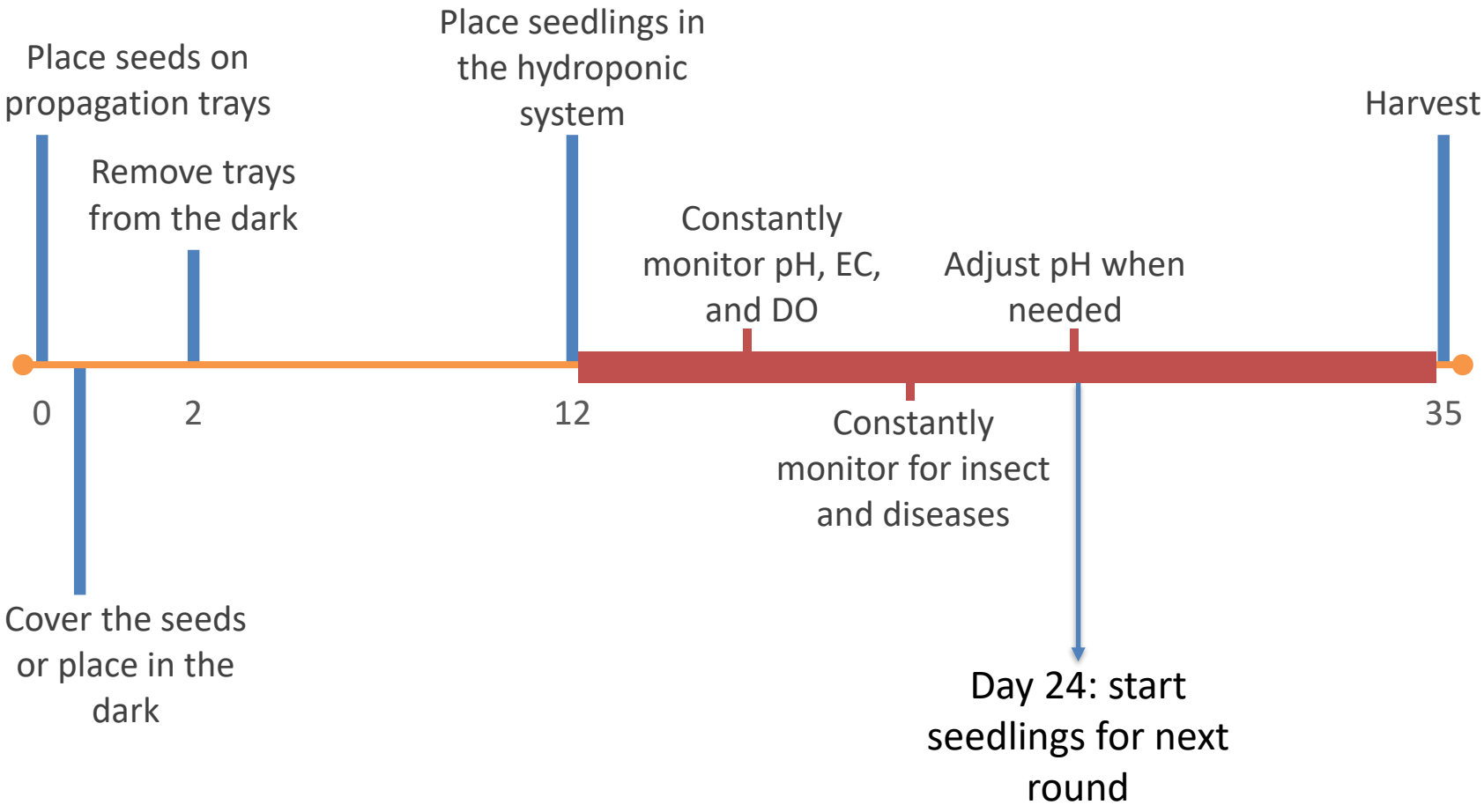
Triangular

- Plant distance: 8”
- Row distance: 6.9”
- Plants in 100 sq ft: 236



12% more plants!

Hydroponic lettuce production timeline



Lettuce types

- Leaf lettuce
- Cos/Romaine
- Bibb (‘Buttercrunch’)
- Iceberg (crisp head)
- Stem or ‘celtuce’
- Heat tolerant
- Downy mildew resistant

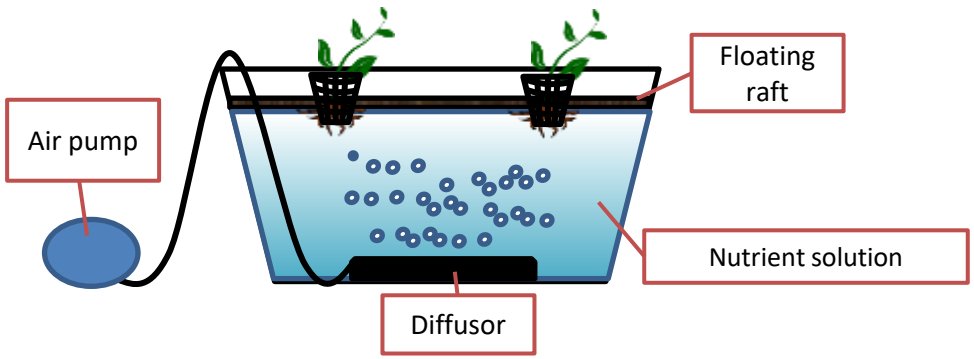

Leaf lettuce


Bibb

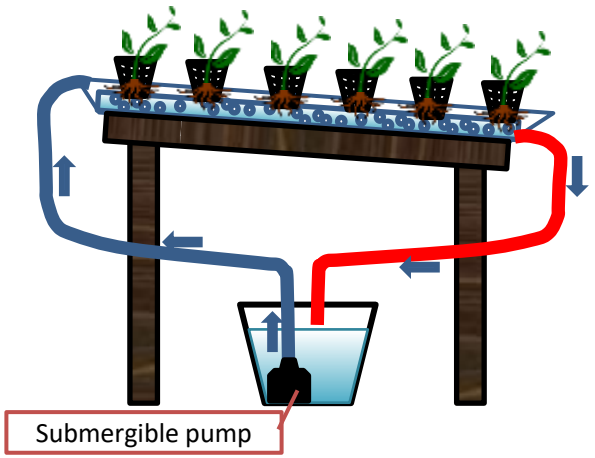

Romaine

Systems adequate for leafy greens

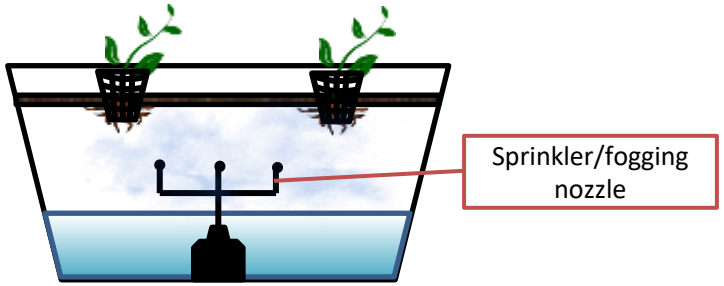
Floating raft/Deep water culture (DWC)



NFT



Aeroponic



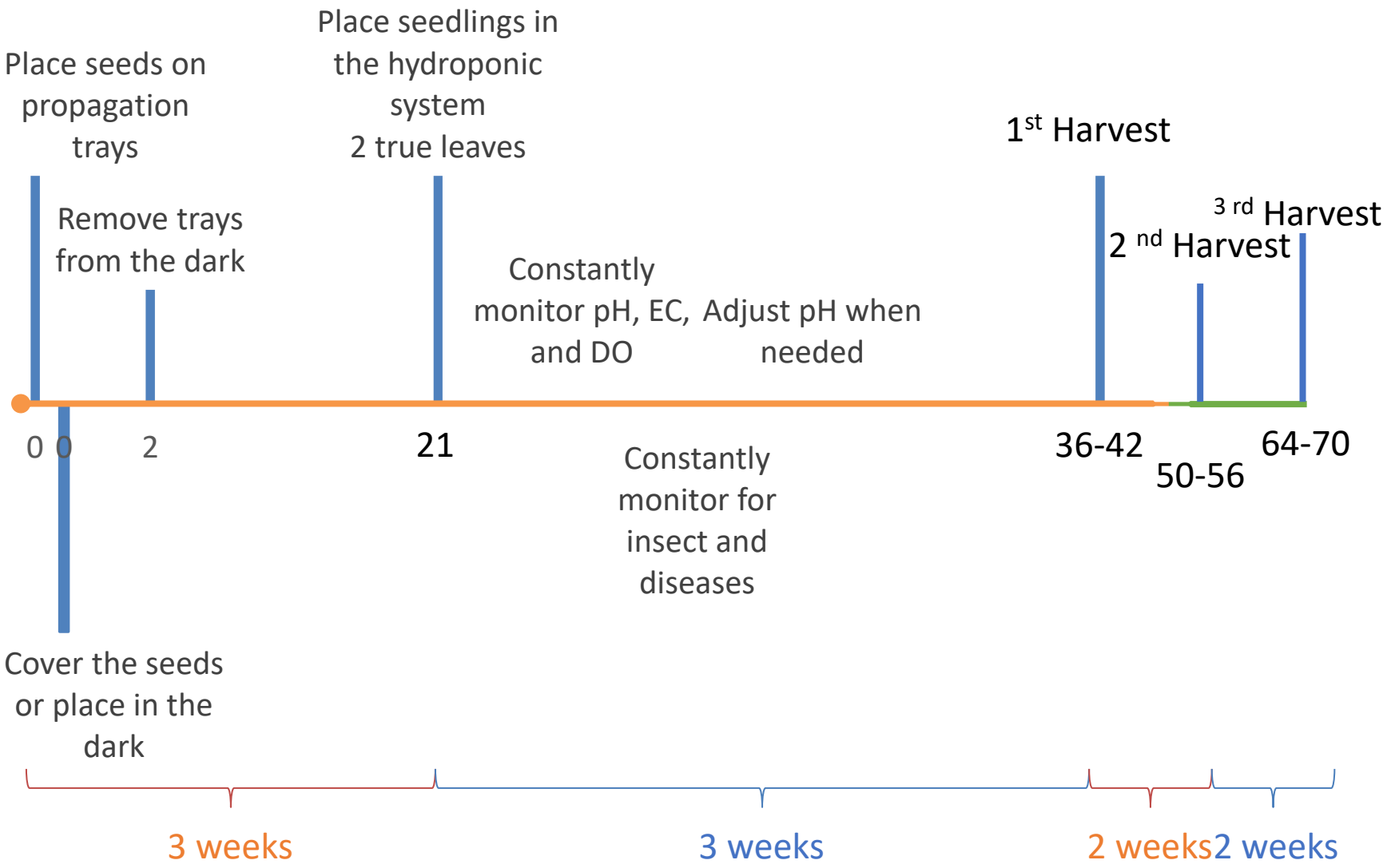
Taking care of lettuce plants

- Place sticky traps near vents, doors, and at the canopy level of the crops to scout for insects
- Scout for insect damage, diseases, yellowing or abnormal growth
- Measure pH, EC, and DO (DWC systems) every two days. Adjust pH when necessary
- Use summer heat resistant varieties in the summer
- Top off with fresh nutrient solution when needed
- Replace nutrient solution after 3 crop cycles/sanitize irrigation system

Lettuce harvest and post harvest

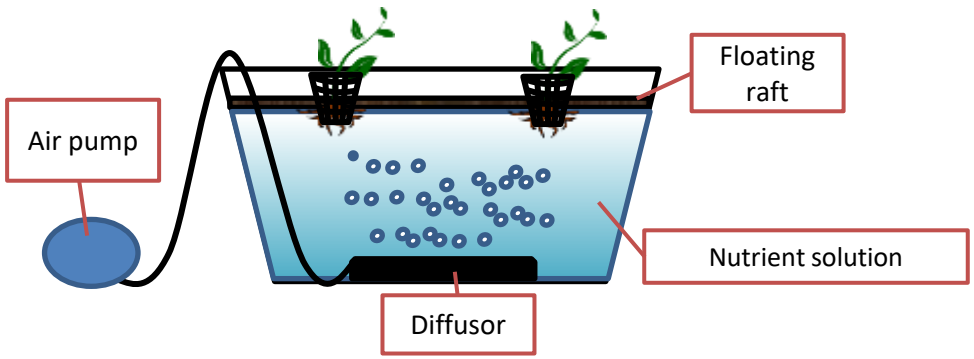
- Harvest:
  - Loose leaves
  - Live plants: prevent water and roots from touching the plants
- Post-harvest: keep at 32°F-34°F and 98-100% relative humidity

Hydroponic basil production timeline



Systems adequate for leafy greens

Floating raft/Deep water culture (DWC)



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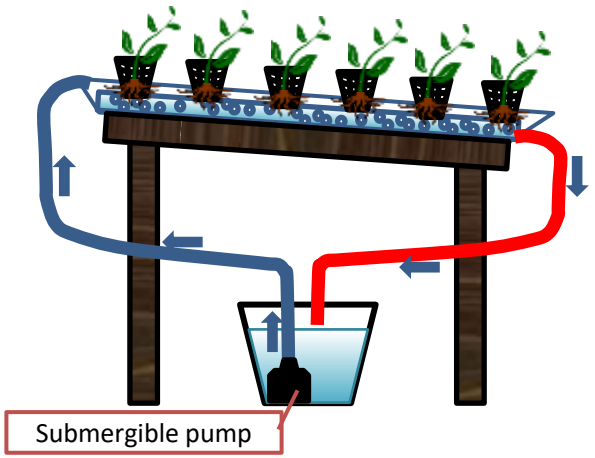
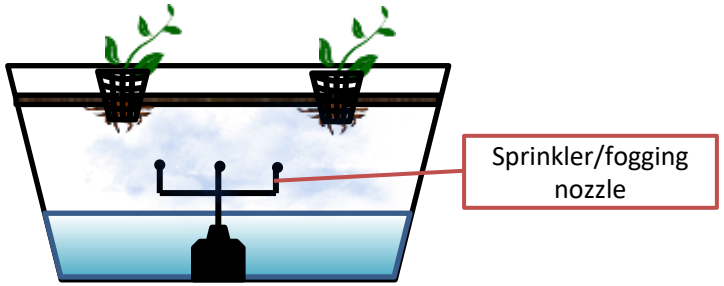


Aeroponic



Choosing basil varieties

- Flavor & production
  - Italian: more productive and longer shelf life
  - Genovese: better flavor profile
- Disease resistance
  - Downy mildew and Fusarium wilt
- Other varieties
  - Purple, Asian/Thai, Citrus, and Greek

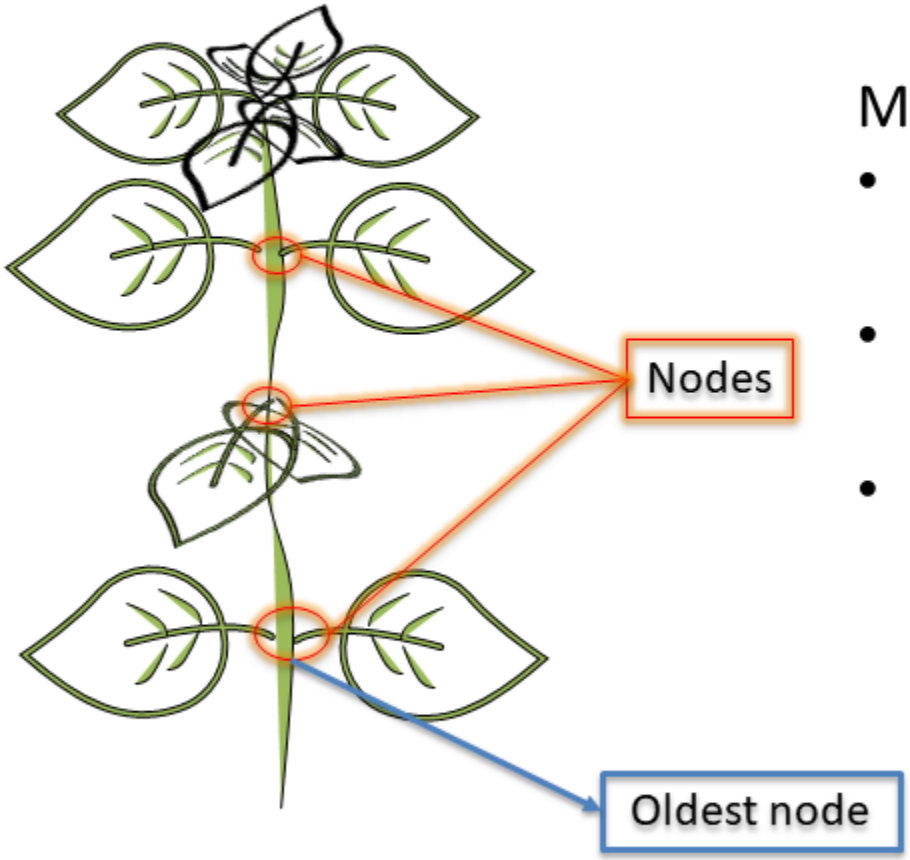
Image source: Wyenandt et al. 2015. https://doi.org/10.1094/PHYTO-02-15-0032-FI

Taking care of basil plants

- Place sticky traps near vents, doors, and at the canopy level of the crops to scout for insects
- Scout for insect damage, diseases, yellowing or abnormal growth
- Measure pH, EC, and DO (DWC systems) every two days. Adjust pH when necessary
- Use disease resistant varieties
- Pinch top bud one week after transplant in hydroponic system
- Top off with fresh nutrient solution when needed
- Replace nutrient solution after 3 crop cycles/sanitize irrigation system

Harvesting and post harvest care

- Harvest (0.5-1 ounces per stem)
  - Single harvest: whole plant
  - Multiple harvests: Cut 3 inches above plant, wait for leaves to regrow, repeat up to 3 times
  - Do not harvest when it is too hot
- Post-harvest: DO NOT REFRIGERATE. Keep the leaves 55°F-60°F at 90-95% relative humidity
- Drying herbs: 125°F for 1 to 4 hours

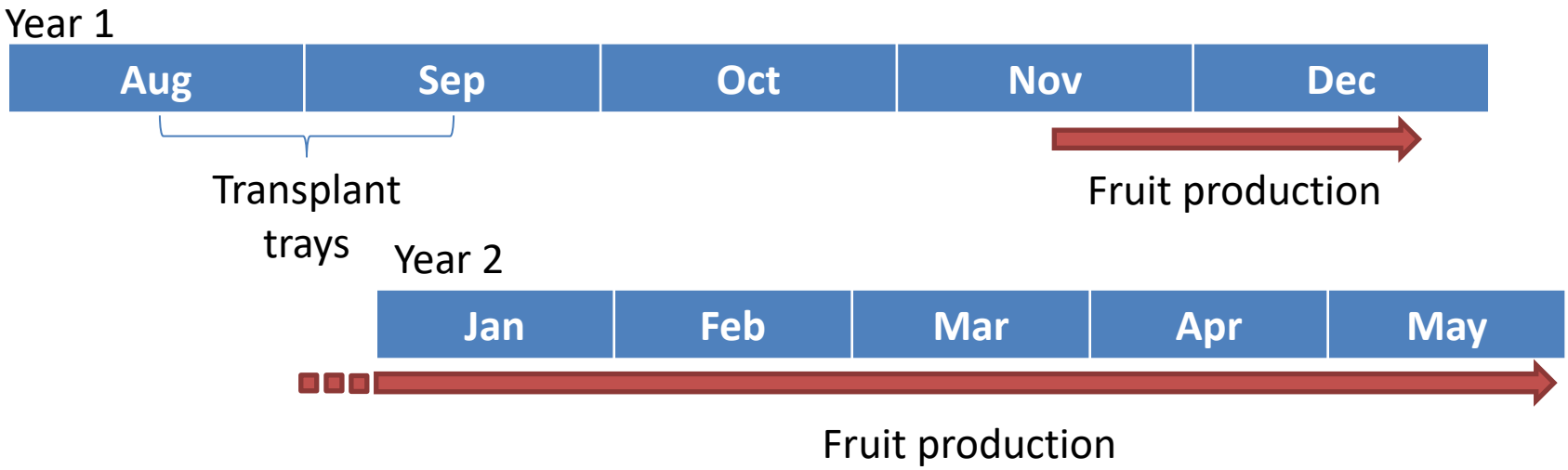


Multiple harvest:

- Cut the stem above the oldest or second to oldest node
- Make the cut 1/8” above the node
- DO NOT CUT THE LEAVES IN THAT NODE

Source: Kubota OSU

Hydroponic strawberry timeline



Harvest every other day

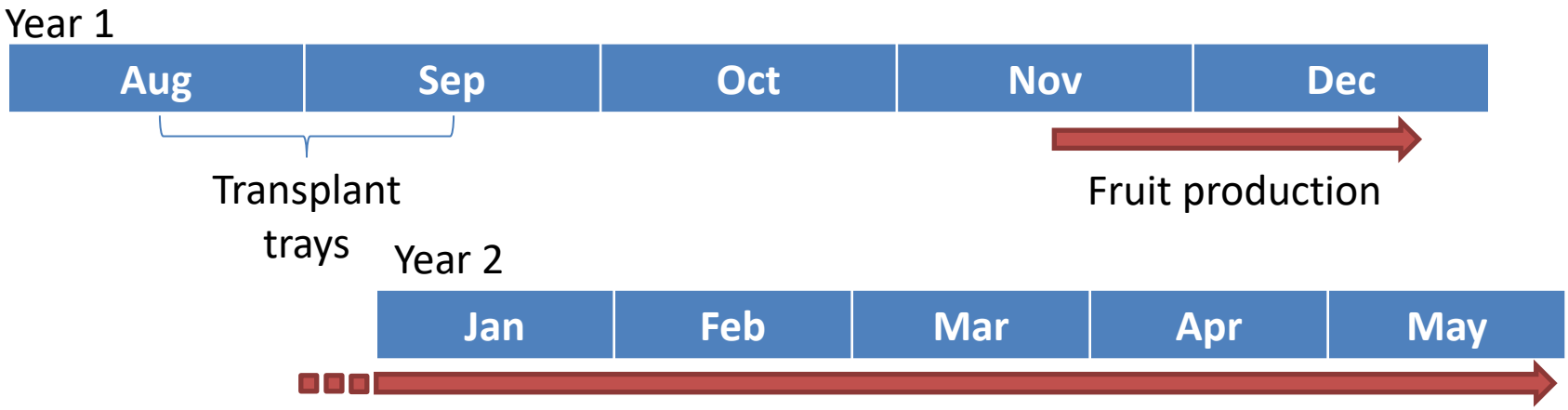
End of harvest season: hot summer temperatures and field crop season

Warm temperatures (>86°F)= flower inhibition and poor taste (night temperature)

Off-season activities: clean, sanitize, and propagate runners (released varieties)

Source: Kubota OSU

Hydroponic strawberry timeline



End son
Off-sea rieties)

The daily average high and low air temperature at 2 meters above the ground.

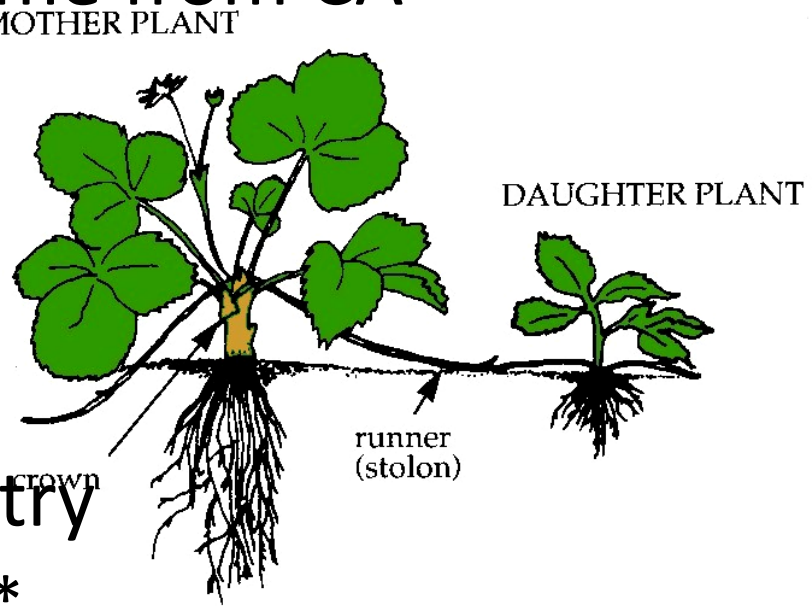
High	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
St. Louis	41°F	46°F	57°F	68°F	77°F	85°F	89°F	87°F	80°F	69°F	56°F	44°F
Springfield	44°F	49°F	59°F	68°F	75°F	83°F	88°F	87°F	79°F	68°F	56°F	46°F
Saint Joseph	38°F	43°F	55°F	66°F	76°F	84°F	88°F	86°F	78°F	67°F	53°F	40°F

Low	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
St. Louis	25°F	29°F	38°F	48°F	57°F	66°F	70°F	67°F	59°F	48°F	38°F	29°F
Springfield	26°F	30°F	38°F	47°F	56°F	65°F	69°F	67°F	59°F	48°F	38°F	29°F
Saint Joseph	19°F	23°F	34°F	44°F	55°F	64°F	68°F	65°F	56°F	45°F	33°F	23°F

Source: galaku.com

Strawberries

- 90% of strawberries come from CA
- Hydroponic systems
  - NFT**
  - Bucket (2L/0.5 gal min)
  - Grow bag
- Planting material industry
  - Vegetative propagation*
  - Transplant production
  - Greenhouse fruit production



*Commercial cultivars are protected by a **20-year patent protection**.

YOU ARE NOT ALOWED TO PROPAGATE COMMERCIAL CULTIVARS

You need a license agreement and pay royalty fees

You have to buy plants from nurseries.

Cultivar types

- **Short-day/June bearing**: flower buds develop in short days fall/early spring (days with <14 h). *You can control the environment to time production (short day and cool conditions) $$ conditioning*. 59-79° F
- **Facultative/long day plant**: flower buds develop in long days with temperatures under 60°F
- **Day neutral/Ever-bearing**: flower and fruit development inhibited with temperature over **86°F**. *Year-round production*. 59-86°F

USDA Strawberry germplasm: https://www.ars.usda.gov/pacific-west-area/corvallis-or/national-clonal-germplasm-repository/docs/ncgr-corvallis-fragaria-germplasm/

Choosing a strawberry cultivar

- Yield and quality
  - Trade off between yield and taste
- Fruit shape, color, size, flowers per cluster
- Photoperiod response
- Dormancy-inducing short day
- Disease resistance
- Insect resistance
- Chilling requirement (not relevant for greenhouse production)

Proven in hydroponics: Albion

Planting material

- **Frigo plants**: stored bare roots, you will need to propagate in plugs or trays. Jan-Jun
- **Fresh dug green plants:** bare roots. Sep-Nov
- **Seeds:** 10-12 weeks to transplant
- **Transplants in plugs:** grown from frigo plants, rooted runner tips, or seeds. Aug-Oct
  - Tray plants 125-250mL cell multiple crowns
  - Plug plants 100 mL cell single crown
- Bigger transplants are better for hydroponic
  - At least ½ inch crown
  - 4-5 leaves at least
  - Flower initials desired
  - White healthy roots
  - No diseases

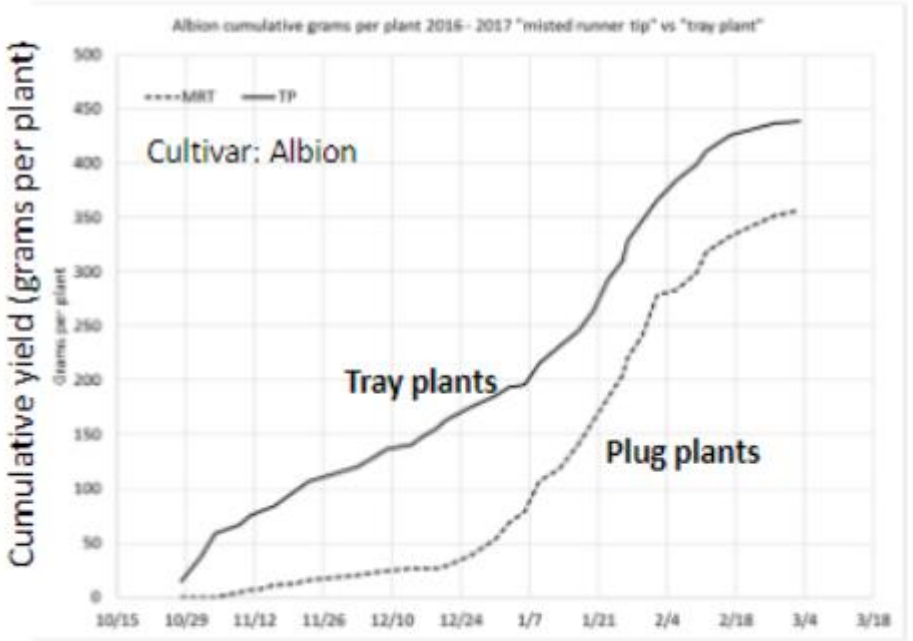
Comparison of small ("rooted tip plug") vs. large ("tray plant") planting materials

38-count **plugs**
(100 ml substrate)
Single crown
3-4 leaves

Tree-band **trays**
(350 ml substrate)
Two crowns
6-8 leaves

3 oz

11 oz



(Kroggel and Kubota, unpublished data)

The Ohio State University
College of Food, Agricultural, and Environmental Sciences

Environment control

Night temperature: 50-55°F (not cooler than 46 °F or warmer than 60 °F)

- Flower size larger flower and fruit at low temp
- Fruit quality lower acid at low temp

Day temperature: 59-86°F for flowering and 70-75°F for vegetative (propagation)

Relative Humidity: 60% day, 95% for 3 h at night

DLI: min10-12 mol/m^2/day **optimum** 15-25 mol/m^2/day. Avoid >30 mol/m^2/day

Rootzone pH: 5.5-6.5

CO_2: 800-1000ppm

Pollination

Hydroponic strawberry nutrient requirements

Element	Yamazaki/Jack's	Tochigi	Chem-Gro™
NO_3-N	70	111	102
NH_4-N	7	10	3.6
P	15	30	12
K	117	156	120
Ca	40	86	85
Mg	12	22	30
S	(16)	11	--
Micronutrient	Ranges for berry formulations		
Fe (Chelated)	2 - 3	Cu	0.02 – 0.5
B	0.3 – 0.8	Mo	0.02 – 0.08
Mn	0.55 – 1.5	Zn	0.03 – 0.33

Unit: ppm or mg/L

For every 10 L add

- 5 g of 8-10-26
- 2.5 g of 15-0-0
- 1.5 g of Epsom salts

- Jack's two bag system: 8-10-26 + 15-0-0

Source: Kubota and Kroggel OSU

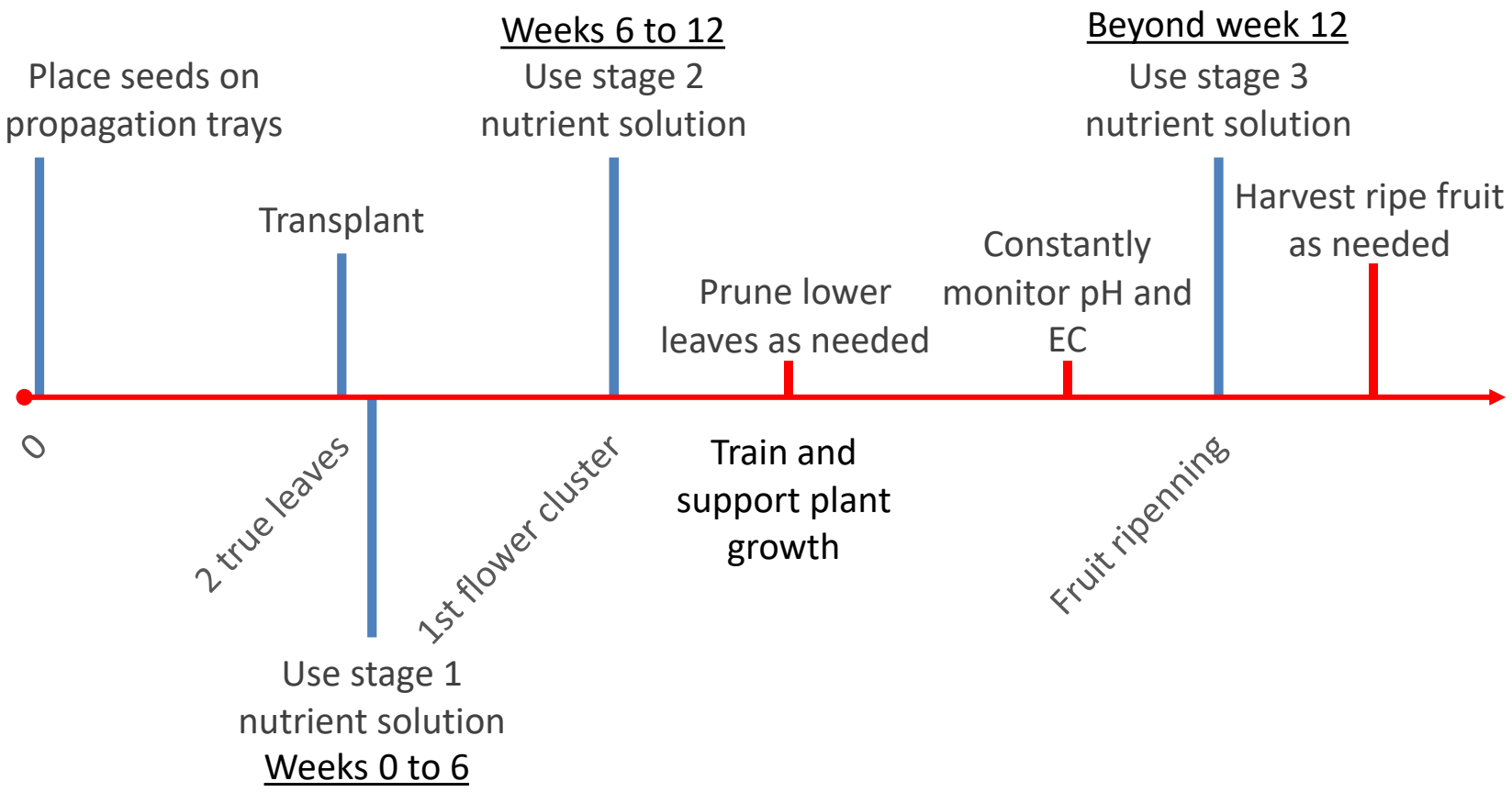
Media and fertility

- Use media mixes with good draining capacity
- Drain 20-30% of the irrigation water
- 6-12 irrigation events (200-400 mL per plant per day)
- High nitrogen fertilization triggers vegetative growth. Strawberries prefer 5-10% of total N from ammonium

Hydroponic strawberry yields & quality

- Greenhouse (GH) yield: 5-10 kg/m^2 (10 plants/m^2) in 8-month season (2-month grow + 6-month harvest) (field in CA 3kg /m^2)
- GH >10g per fruit acceptable (field 20 g per fruit)
- Brix (total soluble solids) GH: 9%desirable (7% field)
- Titratable acidity GH 0.9% (field 0.8%) Brix:acidity ratio 1.0

Hydroponic tomato production timeline

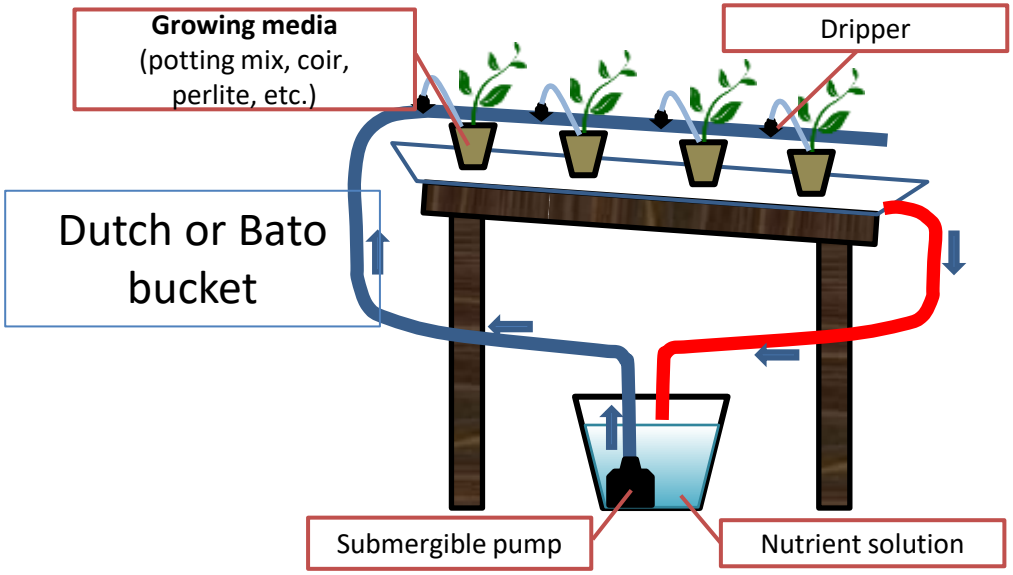


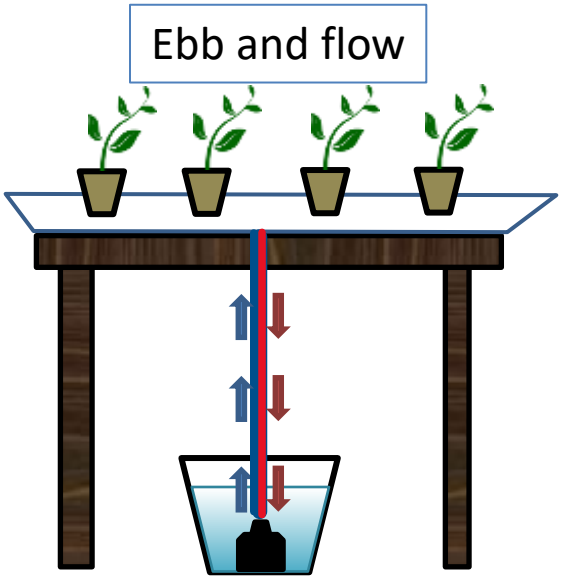
Tomato varieties

- Determinate vs Indeterminate
- Heirloom
  - Pre 1950's
  - Higher retail price, low yields, and susceptible to diseases
- Size/types:
  - Slicers: Beefsteak (large) globe (regular)
  - Plum/Roma paste/processing tomato
  - Cherry and grape: small size for fresh consumption
- Check for disease, insect, and abiotic disorder resistance

http://www.vegetablemdonline.ppath.cornell.edu/Tables/Tomato_2013.pdf

Systems adequate for vine crops





Taking care of tomato plants

- Place sticky traps near vents, doors, and at the canopy level of the crops to monitor for insects
- Measure pH and EC every two days and adjust pH when necessary
- Walk through and observe the plants for insect damage, diseases, yellowing or abnormal growth
- Prune lower leaves and adjust plant on the trellis
- Tomatoes need pollination!
- Replace nutrient solutions when needed

Pollinating tomatoes

- There are no pollinators inside a greenhouse or a vertical farms
- Pollination is needed to increase yield and fruit size
- You can order a box of bumblebees that will last for 12 weeks, and it is good for 1,400 to 5,700 sq ft (too many can damage flowers)
- Tap the trellis wire twice a day at least 3 days a week
- Use electric air blowers every day for 5 seconds


THIS IS NOT JUST A BUMBLEBEE
THIS IS NATUPOL
THIS IS NOT JUST A BUMBLEBEE
THIS IS NATUPOL

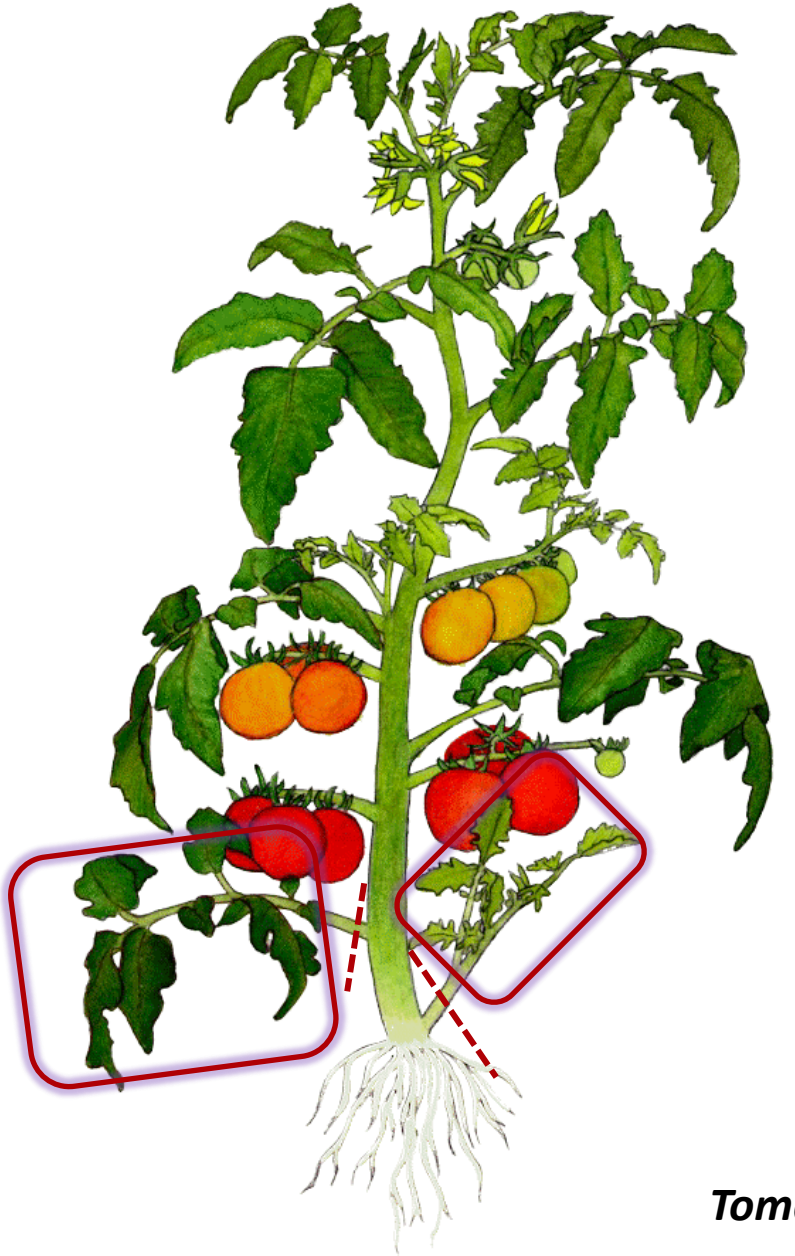
Trellis system

Highwire system: 20 pounds per foot
Training: central leader

Pruning

Improved air circulation = Less disease pressure

Makes it easy to train the tomato plants

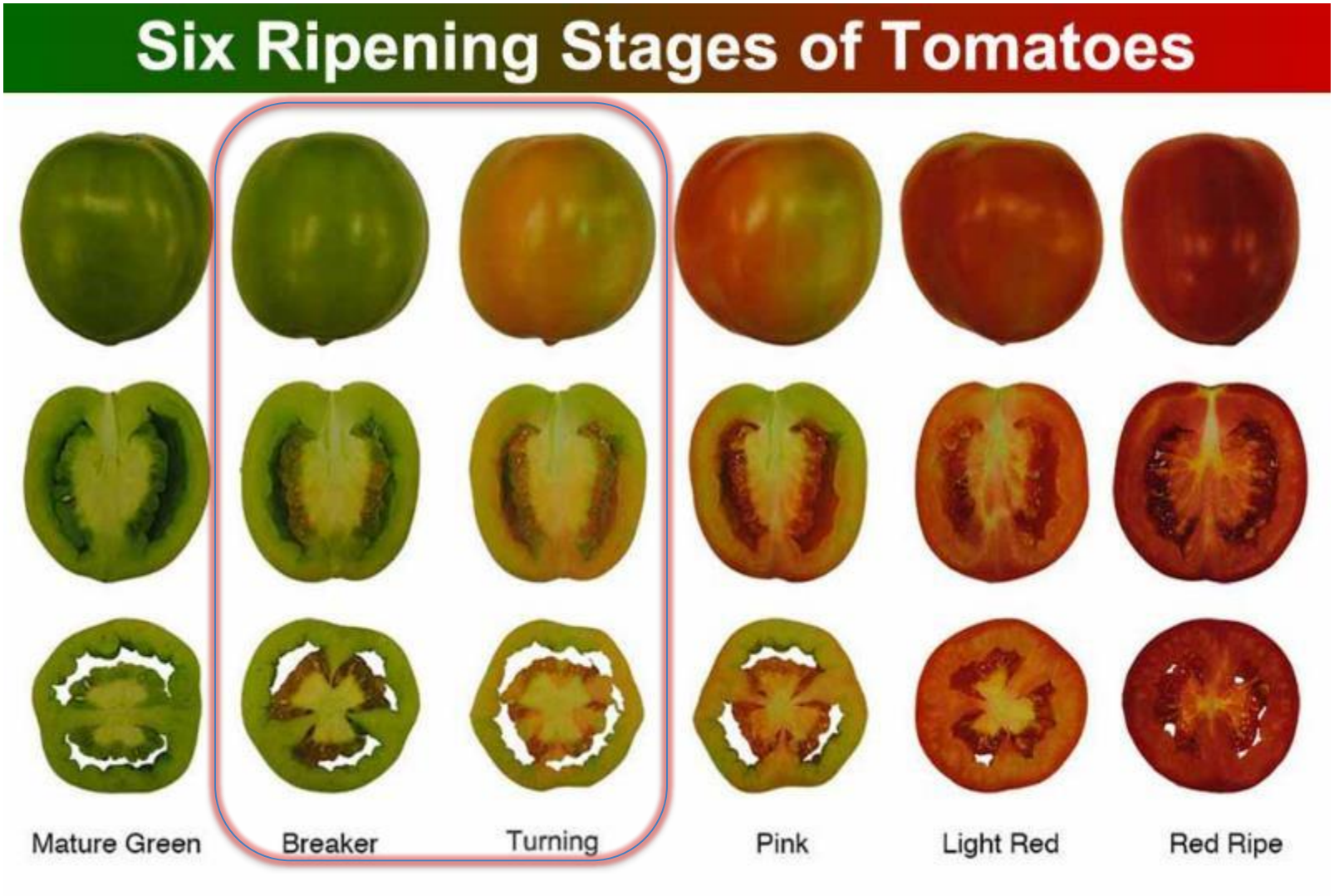


Remove any suckers

Remove lower leaves no longer needed for production: all leaves under the first fruit cluster

Tomato plant illustration by K. Tomlinson
Available at
https://cals.arizona.edu/hydroponictomatoes/pruning.htm

Tomato harvest and post harvest



Source: Organic Farming and Gardening School

Tomato harvest and post harvest

- Harvest: Lift and pull
  - Green: long distance shipping and needs ethylene treatment to induce ripening
  - Ripe: shorter shelf life but with better taste
- Post-harvest:
  - Mature green: 58-60°F lasts 21-28 days
  - Pink: 48-50°F lasts 7-14 days
  - Red: 55 °F lasts 2-4 days
  - Relative humidity: 85-95%

Topics

- Nutrient solutions definitions
  - pH
  - Electrical conductivity
  - Dissolved oxygen
  - Alkalinity
- Nutrient requirements
- Making nutrient solutions
- Monitoring nutrient solutions
- Plant production timeline and steps
- Common problems

Common problems

1. Environmental problems
2. Plant diseases
3. Insect pests
4. Algae

Abiotic vs biotic

- Biotic problems: caused by a living organism (develops over time with sporadic occurrence)
- Abiotic problems: caused by the environment (instant and general occurrence)

What is wrong with these lettuce plants?

Bolting

BOTH CAUSED BY HIGH TEMPERATURE!

Temperature

- Lettuce: root 75°F; air→Day 68°F-75°F (never over 77°F) →Night 60°F-65°F
- Tomatoes 77°F
- Basil 70-75°F
- Spinach: root 72°F; air 61°F - 91°F

(Thompson et al., 1998; Tindall et al., 1990; Lee and Takakura, 1995,)

Temperature and diseases

20-30% of losses happen during summer

Plant’s comfort
Pathogen’s comfort
Dissolved oxygen and root health

Abiotic disorders

- Leggy plants with pale green/yellow foliage and long internodes: Poor lighting or overcrowding.
- Burned tips: high salinity (high EC), excessive fertilizers (improper mixing and preparation)
- Yellow foliage: lack of nutrients

Not a disease!

Blossom end rot

Caused by environmental conditions that limit the absorption of calcium. Even when calcium levels are adequate in the soil!

Calcium enters the roots with water!

Factors that will limit water uptake include days with high relative humidity and inconsistent watering.

Not a disease!

How to prevent blossom end rot?

- If growing indoors make sure you have a fan exchanging air around the plants to avoid stagnant humid air.
- Open the greenhouse/high tunnel vents to allow for air exchange and lower air humidity. (1 exchange/hour)
- Remember to keep the soil moist but not saturated when watering.
- Avoid prolonged periods of drought, specially when the fruits are growing.

Not a disease!

Caused by high temperatures, inconsistent watering, and intense sunlight exposure can affect fruit development and ripening.

Solutions

- Increase airflow to lower air temperature
- Use of shade cloth rated between 20 to 50% shade.
- Shade cloth will lower air temperature between 6 to 9 °F and should be installed when temperatures are going to be over 85°F.

BIOTIC ISSUES

Plant pathogen dispersal

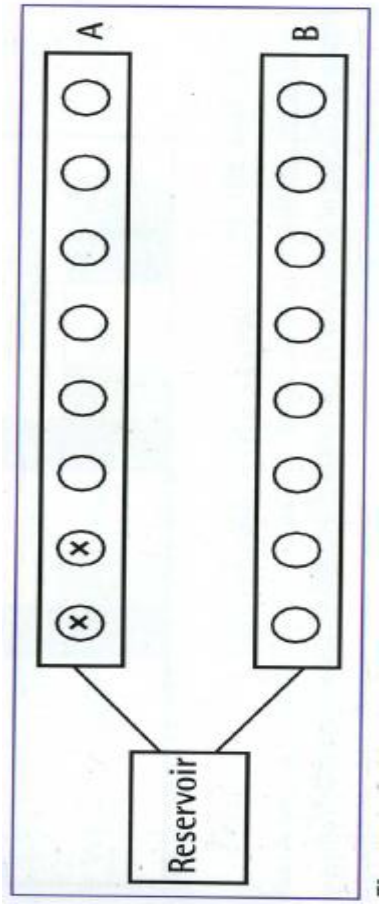


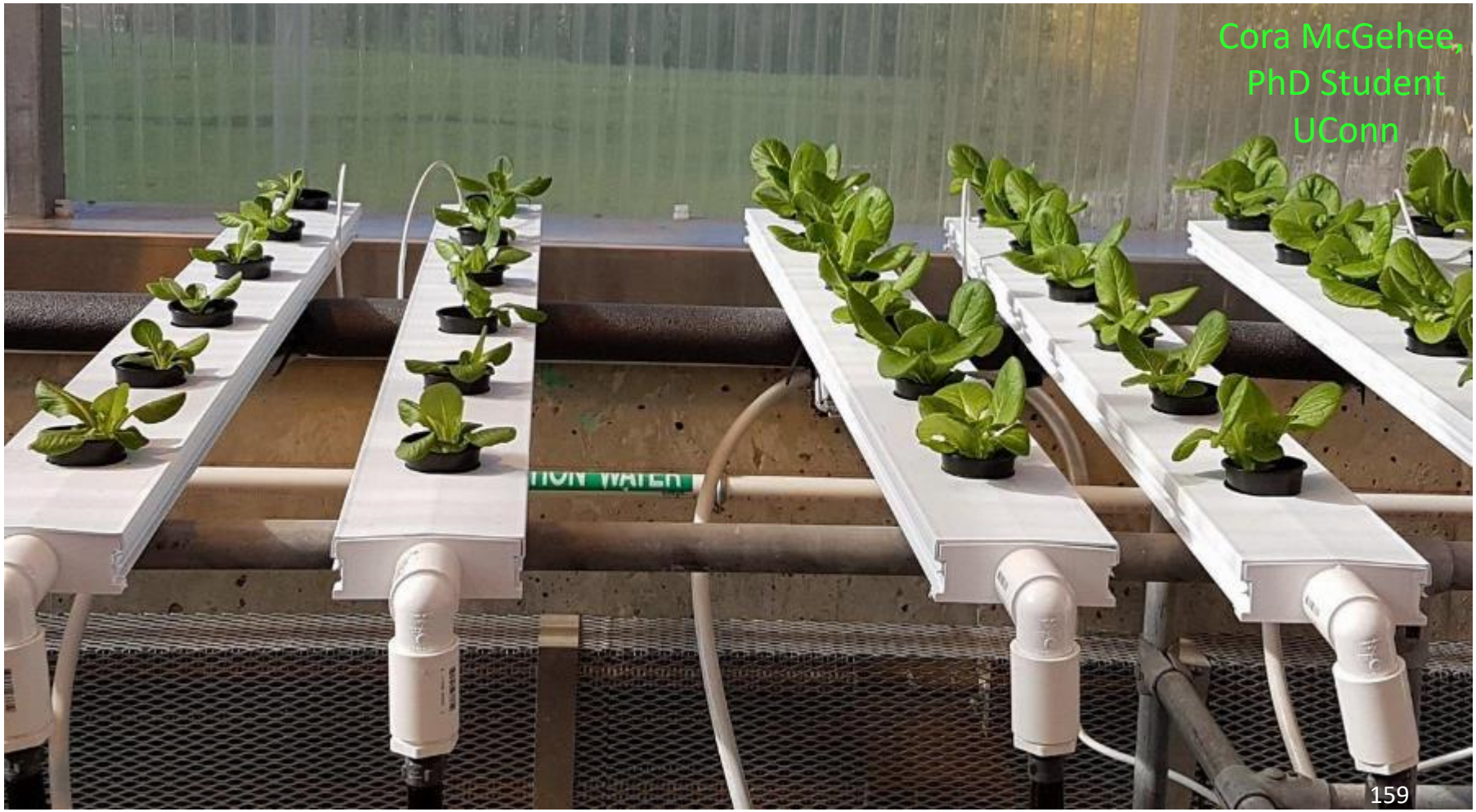
Fig. 4. Mortality of pepper plants on the inoculated and noninoculated side of a two-sided ebb-and-flow cultural system in the **(A)** absence or **(B)** presence of a surfactant in the recirculating nutrient solution. X = the inoculated plants that served as the source of secondary inoculum.

Stanghellini et al., 2000

Common pathogens in hydroponics

- *Pythium* spp.
- *Phytophthora* spp.
- *Thielaviopsis basicola*
- *Xanthomonas*
- *Sclerotinia*
- *Botrytis*
- Powdery and downy mildew

Biocontrol of waterborne diseases:
Still not compatible with hydroponic production



- https://youtu.be/ODCVqnjou58

Diseases

- Damping-off and root rots: Use high quality water or consider treating the water. Use a *Trichoderma* drench as preventive biocontrol.
- Mildews and white mold (Sclerotinia): Increase air circulation especially horizontal flow. Increase plant spacing. If growing indoors, consider a dehumidifier.
- Botrytis (gray mold): likes cool and wet weather. Avoid watering at night. Remove affected plants and improve air circulation.
- Leggy plants with yellow foliage: Lack of light, overcrowding or lack of nutrients.

Preventing diseases: Environment

- Keep plants in their comfort zones: pH, dissolved oxygen, temperature, and proper fertility
- Use good quality water
  - Municipal water ($$) or well water ($)
- Consider water treatment if you don't have access to good quality water
  - Solid separation → Filtration → Sanitation
- Use certified disease-free seeds and resistant varieties
- Ensure good air circulation: spacing and pruning

Preventing diseases: Equipment

- Keep the outside perimeter free of weeds
- Avoid reusing potting mixes
- Start with clean surfaces
  - Wash off debris, scrub with soap, and rinse
  - Sanitize (follow label instructions): quaternary ammonium (Green-Shield®, Physan 20®, and Triathlon®), hydrogen dioxide (ZeroTol®, Oxidate®), peracetic acid (Sanidate®) and chlorine dioxide (Selectrocide™)
- Keep floors clean

Preventing diseases: Control

- When in doubt contact your Extension Specialist
- Use chemical pesticides as last resort
  - Read the pesticide label: This is a binding contract
  - Do you have a pesticide applicator license?
  - Is it labeled for the crop?
  - Is it labeled for use indoors or in greenhouse?
  - Is it labeled to control the intended pest?
  - Do you have the required protective and application equipment?
  - Rotate chemicals (FRAC code) to prevent resistance
- Consider biocontrol options: http://greenhouseipm.org/ipm-basics/ http://anbp.org

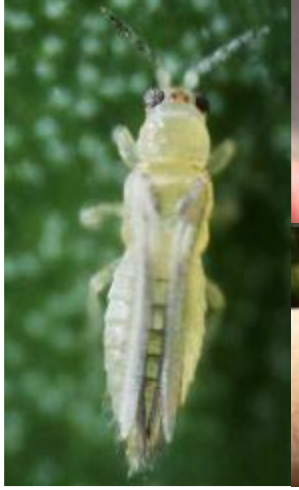
Monitoring for pests

- Use sticky traps to scout for insects
  - At plant height
  - Yellow: fungus gnats, aphids, thrips, whiteflies, and leaf miners
  - Blue: whiteflies
  - One trap per 1,000 square feet
  - Additional traps as needed near vents and doors
  - Always inspect the plants
- Identify the pests and the damage they cause (some transmit plant diseases)
  - Identity will help you identify proper control

Sticky traps

Common insect pests

- Indoor/greenhouse: thrips, aphids, whiteflies, fungus gnat, and shoreflies
- Cultural control: resistant varieties, prevention measures, insecticidal soaps, horticultural oils, neem oil.
- Chemical control: Read the label! The label is the law! Rotate products (IRAC code)
- Biological control: predatory insects and beneficial fungi



Aphids

Chemical control

- You need training to get a private pesticide applicator training
- Always rotate pesticides with different FRAC or IRAC codes to prevent resistance development
- Read the label: this is a legal binding contract
  - Intended pest, for the specific crop, and adequate personal protective equipment
  - Ensures the responsible use of chemical pesticides
- Re entry and pre harvest intervals

Tripping hazard

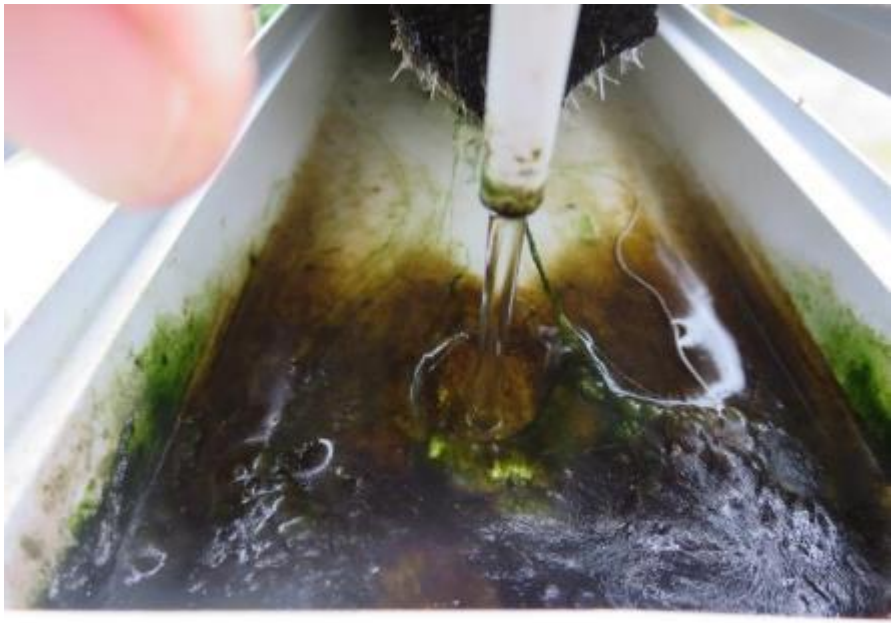
Foul smell

Host insect pest

Toxic to humans

Compete for nutrients

Algae accumulation



Algae in indoor farming facility

Algae control

Factors that affect algae growth:

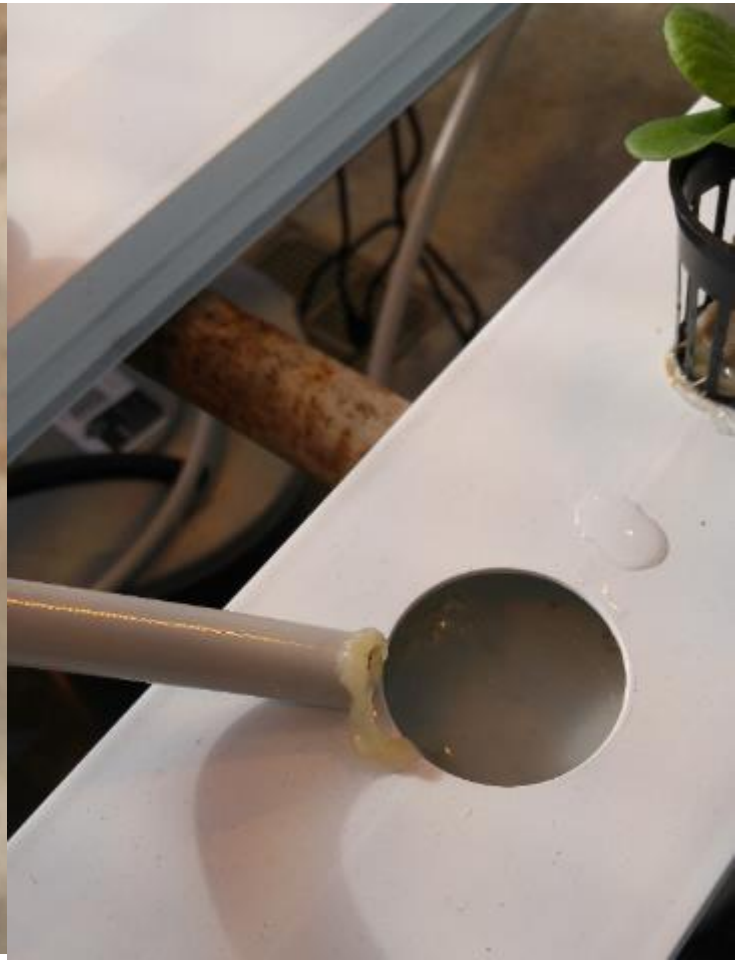
- Nutrients
- Water
- Light

Algicides will also kill plants

Sanitation: Lower initial inoculum

Sanitation: Lower initial inoculum

Organic production: Clogging



Food safety considerations

- Learn how to identify risk of contamination and how to minimize them
- Rodent control
- Worker training (hygiene, health, illness, or injury)
- Quality of the production and postharvest water
- Cleanliness of buildings, equipment, tools, and surfaces
- Pets
- Visitors
- Fertilizers (organic source)
- Provide equipment, training, policies, practices and facilities to minimize risks

Contamination Sources

Humans

Soil

Produce

Animals

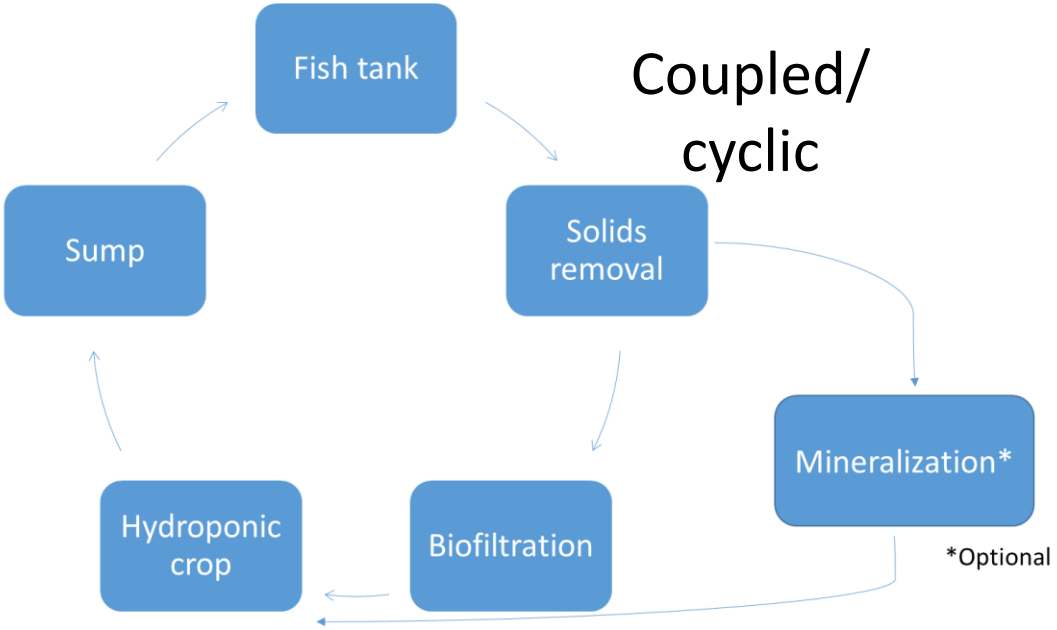
Buildings
Equipment
Tools

Water

Produce Safety ALLIANCE

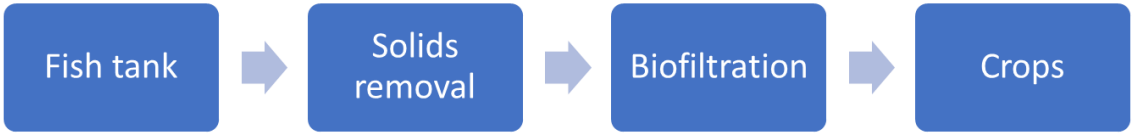
BONUS AQUAPONICS

Aquaponic systems

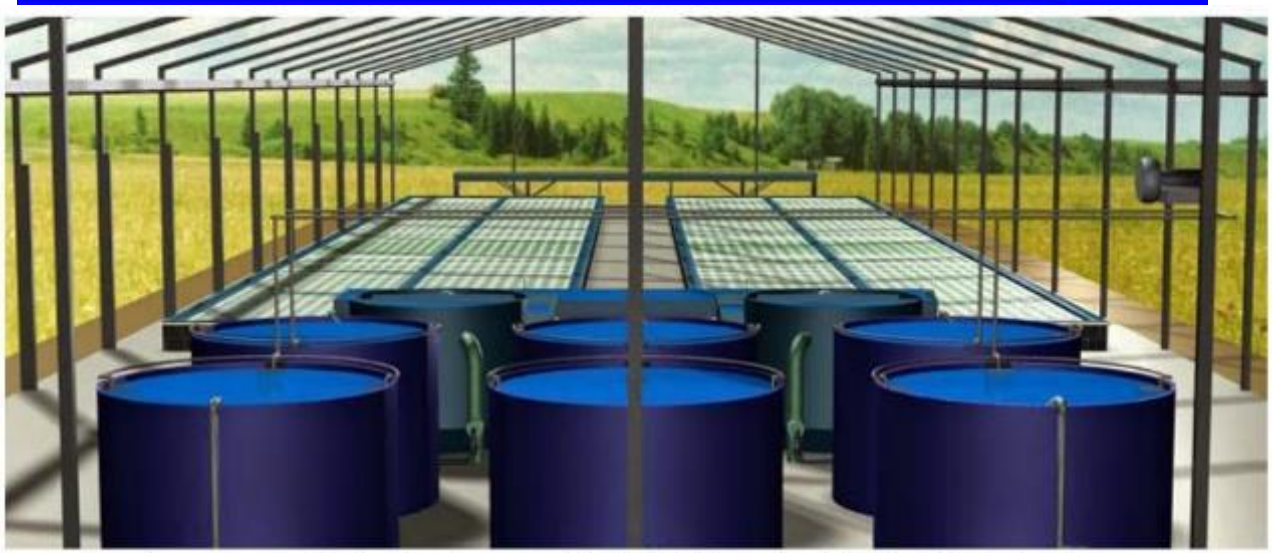


Coupled/ cyclic

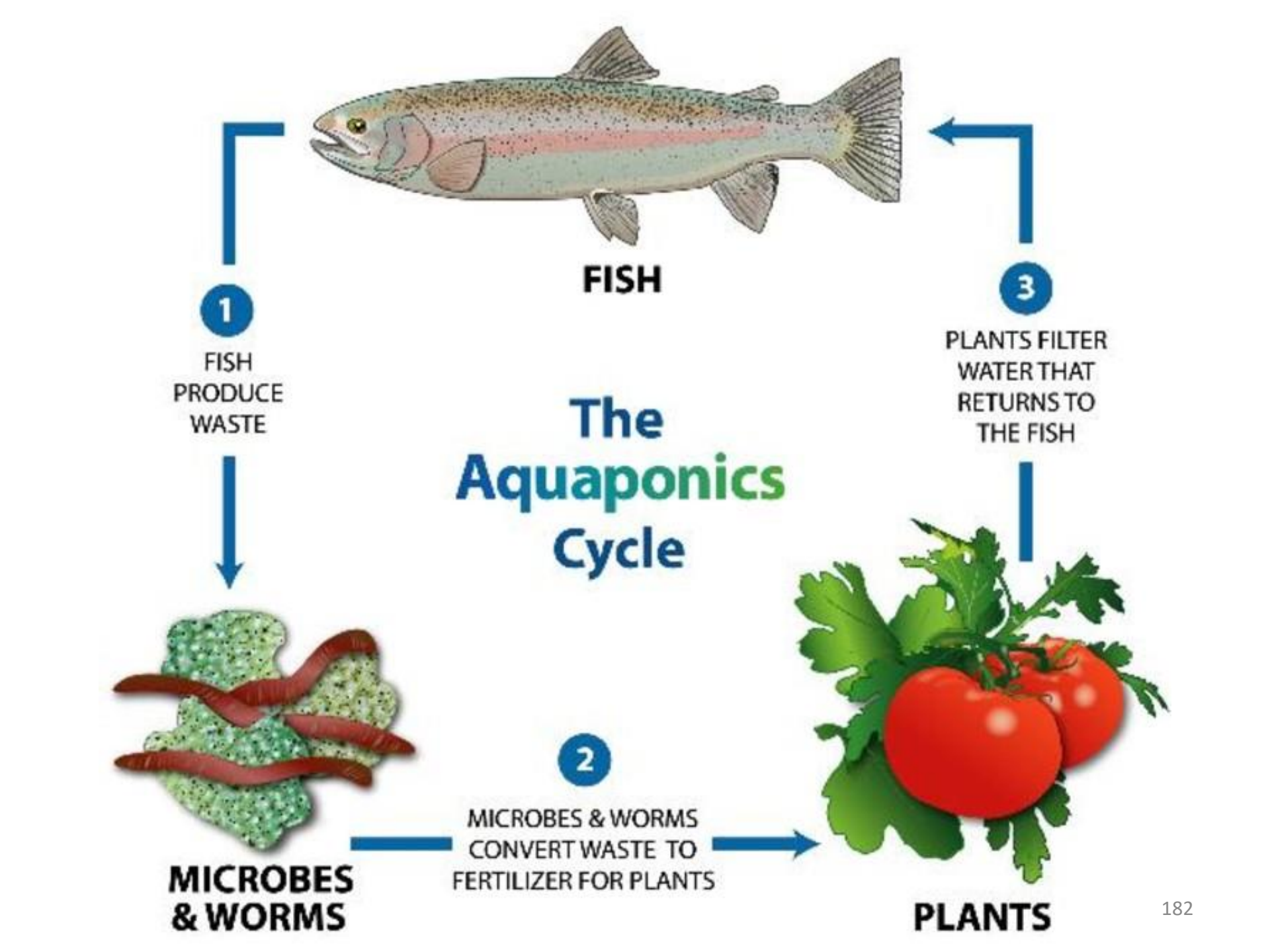
Decoupled/linear



Coupled aquaponic systems



An aquaponics float system based on the UVI (University of the Virgin Islands) design.


FISH
1
FISH PRODUCE WASTE
3
PLANTS FILTER WATER THAT RETURNS TO THE FISH
The Aquaponics Cycle
2
MICROBES & WORMS CONVERT WASTE TO FERTILIZER FOR PLANTS
MICROBES & WORMS
PLANTS

Water quality for aquaponics

- In aquaponic systems, you make compromises to keep the fish, biofilter, and plants in their comfort zones

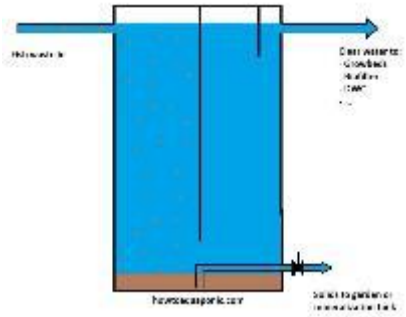
Parameter	Catfish	Biofilter	Lettuce	Tomato	General system
Temperature (°F)	75 - 86	> 68	75	77	75 - 86
Dissolved oxygen (ppm)	5 - 15	> 4	> 6	> 6	6
pH	6 - 8	7 - 9	5.5 - 6.5	5.5 - 6.5	6.8 - 7
Ammonia (NH_3, ppm)	< 1	-	< 1	< 1	< 1
Nitrite (NO_2^-)	0 - 1	-	0 - 1	0 - 1	0 - 1
Nitrate (NO_3^-, ppm)	< 150	-	125 - 150	125 - 225	150

Solid separators

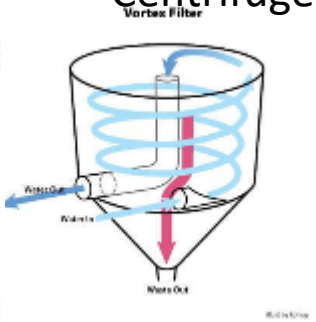
- Non-decomposed material clogs the system, and its degradation lowers the dissolved oxygen.
- Bacteria in the biofilter, fishes, and plants NEED oxygen

GRAVITY

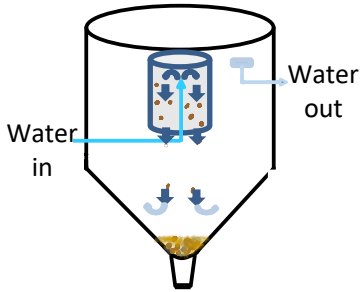
Clarifier



Centrifuge



Radial flow



FILTRATION

Screen filter

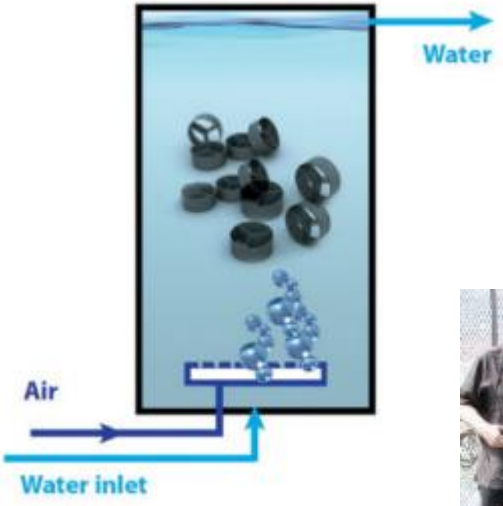
Granular media

Biofilter

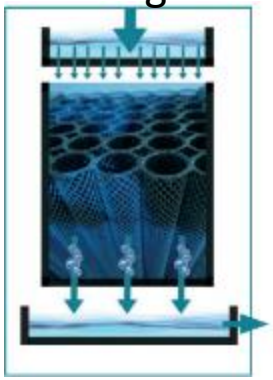
- Bacteria in the **biofilm** transform toxic forms of nitrogen to nitrate (safe for fish and plants)

Granular media

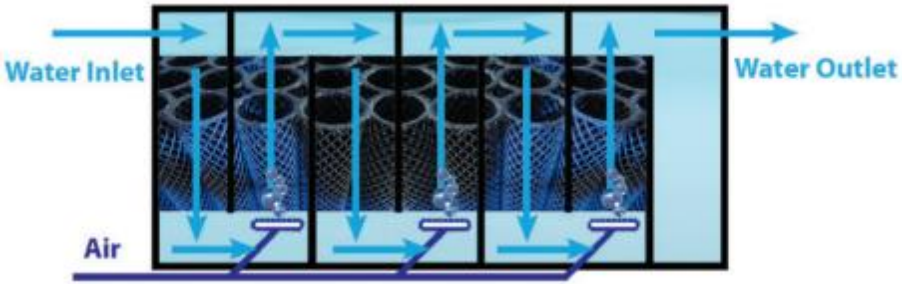
Moving bed biofilter



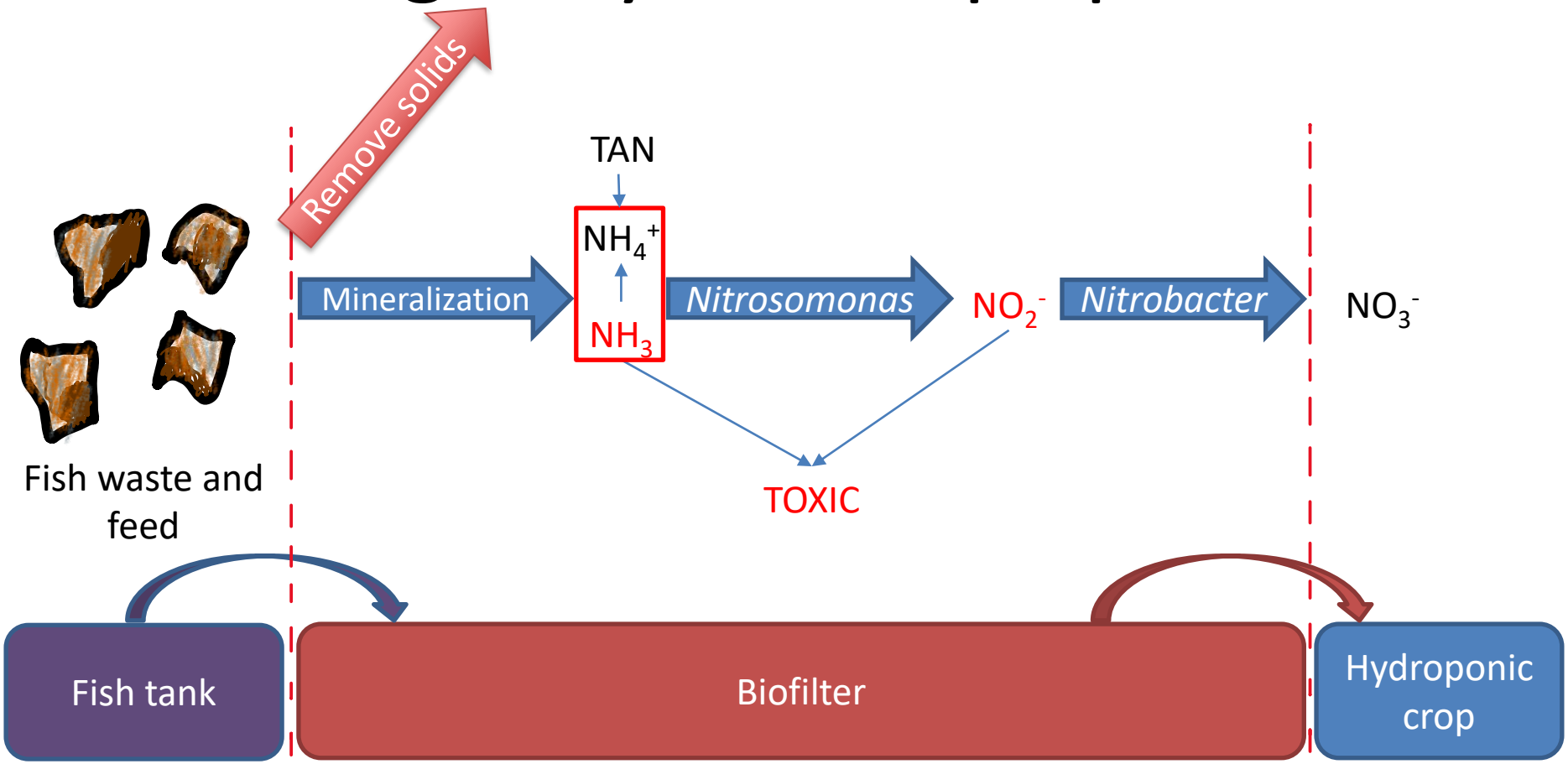
Trickling filter



Fixed bed biofilter



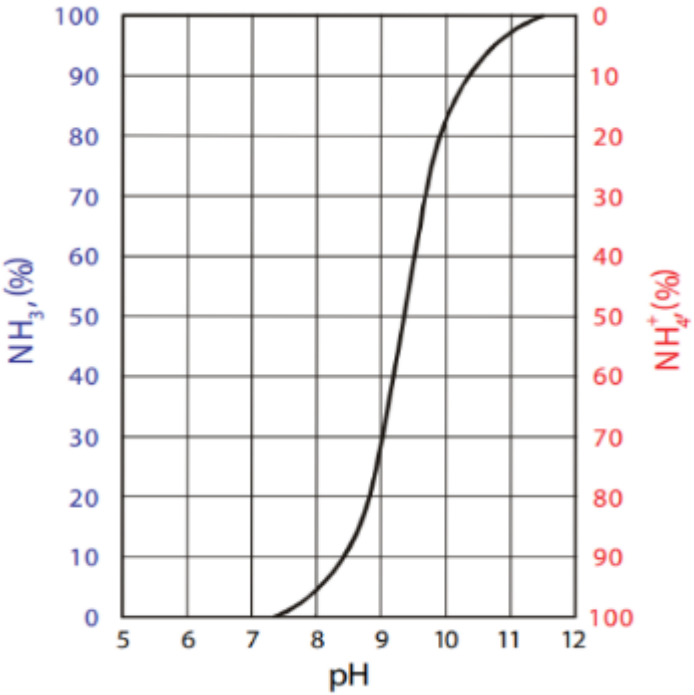
Nitrogen cycle in aquaponics



Nitrogen management determines the success of an aquaponic system!

Total ammoniacal nitrogen (TAN)

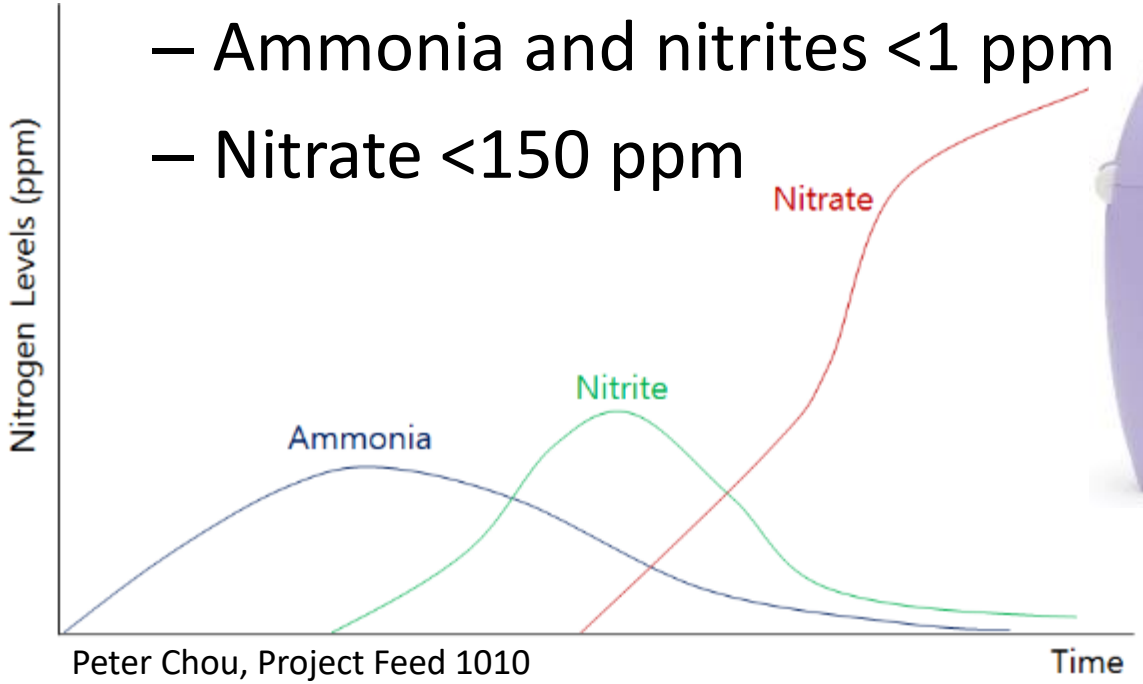
- Includes toxic (NH3) and nontoxic (NH4+) forms.
- The nontoxic form prevails with pH under 7.5 and temperatures under 87°F/31°C



Source: FAO Recirculated Aquaculture Guide 2015

Priming the biofilters

- Fish cycling
- Cycling without fish: use ammonia
- Use meters to know when the biofilter is ready
  - Ammonia and nitrites <1 ppm
  - Nitrate <150 ppm



Peter Chou, Project Feed 1010

Fish:plant Ratio

- Ratio depends on the amount of fish feed used
  - Temperature: fish metabolism
  - Fish species and growth stage
- For DWC systems: 60 – 100 g/m^2/day
  - 100 g of feed per day = 1 – 1.6 m^2
  - 100 m^2 of production = 6,000 – 10,000 g/day
  - NFT uses 25% of the requirements for DWC
- On average fishes will consume 1.5 – 2% of their weight per day
- Ideally measure nitrogen forms and ajust the fish:plant rates
- You might need to supplement plants with added fertilizers