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2 Hydroponic nutrient solutions

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NORTH CENTRAL SARE
Sustainable Agriculture Research & Education

Topics

1. Introduction
2. Factors that affect nutrient solutions
   - Water quality
   - pH
   - Electrical conductivity (EC)
   - Dissolved oxygen (temperature)
   - Crop requirements by growth stage
   - Water alkalinity (hardness)
3. Preparing nutrient solutions
4. Monitoring nutrient solutions
5. Organic fertilizers and aquaponics

Water + Fertilizers = Nutrient solution

A great nutritional program begins with good water quality.

The purpose of the nutritional program is to:

- ✓Provide all essential elements.
- ✓Provide the necessary quantity for the optimum plant development.
- ✓Promote nutrient availability and absorption.

  → pH management.

Comfort zones

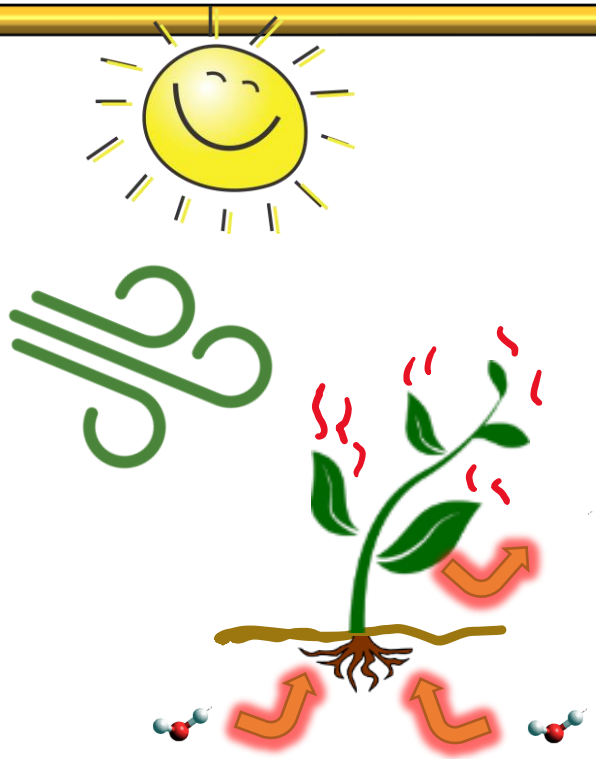
- Chill weather
- Nice view
- Cozy
- Warm cup of coffee

PLANTS ALSO HAVE COMFORT ZONES!

Keeping plants in their comfort zone

1. Provide adequate amounts of essential nutrients
   - Prepare nutrient solution
   - Electrical conductivity (EC)
2. Monitor and adjust the pH of the nutrient solution
   - Affects availability and absorption of nutrients
3. Manage the water temperature and dissolved oxygen
4. Adequate lighting
5. Air flow

Air flow and water absorption



Extension
University of Missouri

Air flow and water absorption

Brendan Morrison and Allayana Darrow. The Planet Magazine. https://theplanetmagazine.net/a-vertical-horizon-586ff6f67e98

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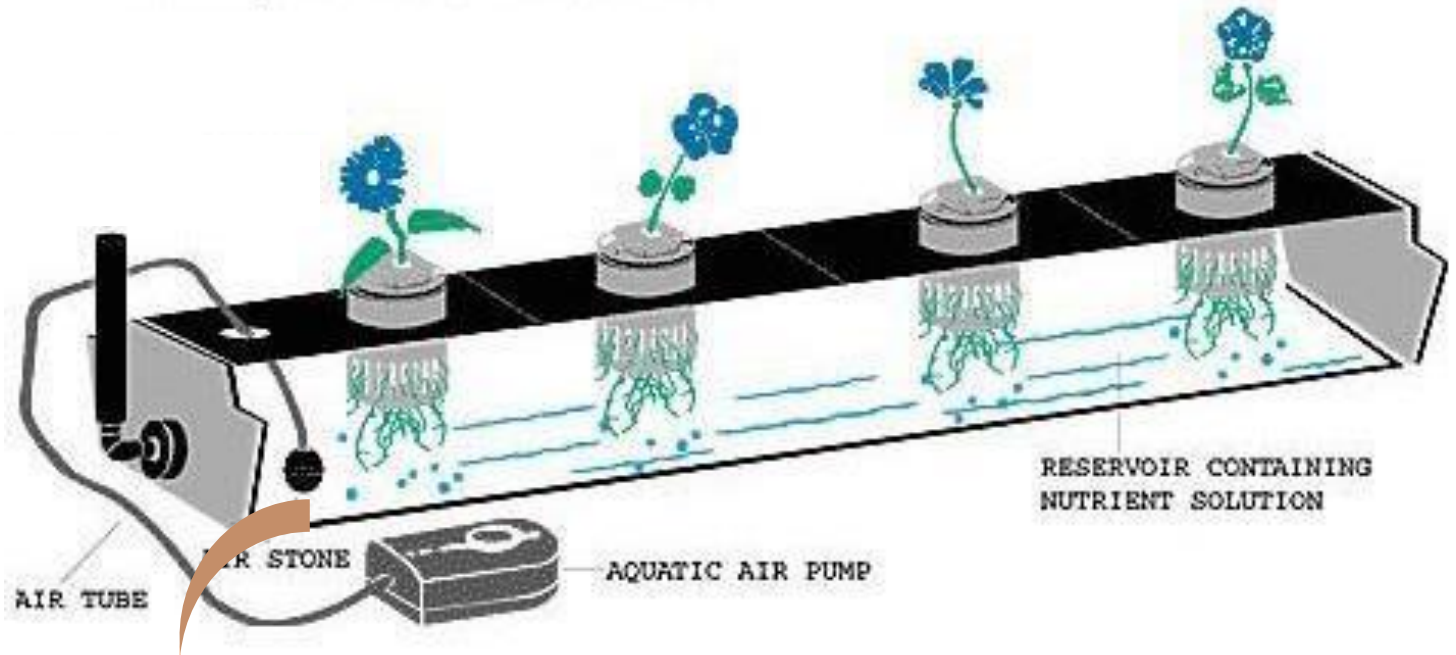
Factors that affect the nutrient solution

Plant's comfort zone!



- Water quality
- pH
- Electrical conductivity (EC)
- Nutrient requirements (for each crop and growth stage)
- Water alkalinity
- Dissolved oxygen

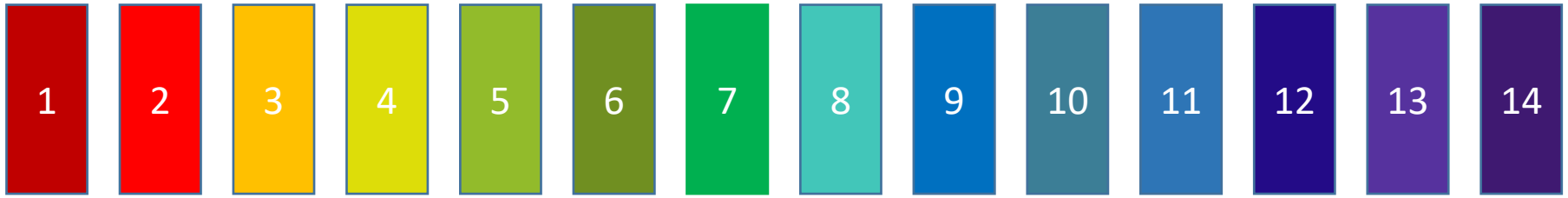
EMW-400 : Water Irrigation Suitability

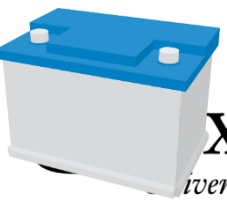
Components		Results mg/L	meq	Target Ranges (mg/L)	Acceptable (mg/L)
MAJOR CATIONS					
Potassium	K	3.73	0.10		<100
Calcium	Ca	11.22	0.56	25 - 75	<150
Magnesium	Mg	3.23	0.27	10 - 30	<50
Sodium	Na	40.54	1.76	0 - 20	<50
MAJOR ANIONS					
Phosphate	PO4	0.71	0.02		<90
Sulfate	SO4	18.97	0.39	0 - 120	<240
Chloride	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			

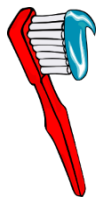
pH

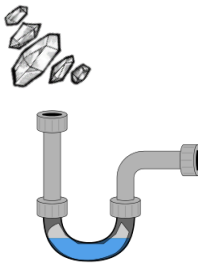
What is pH?

- 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.





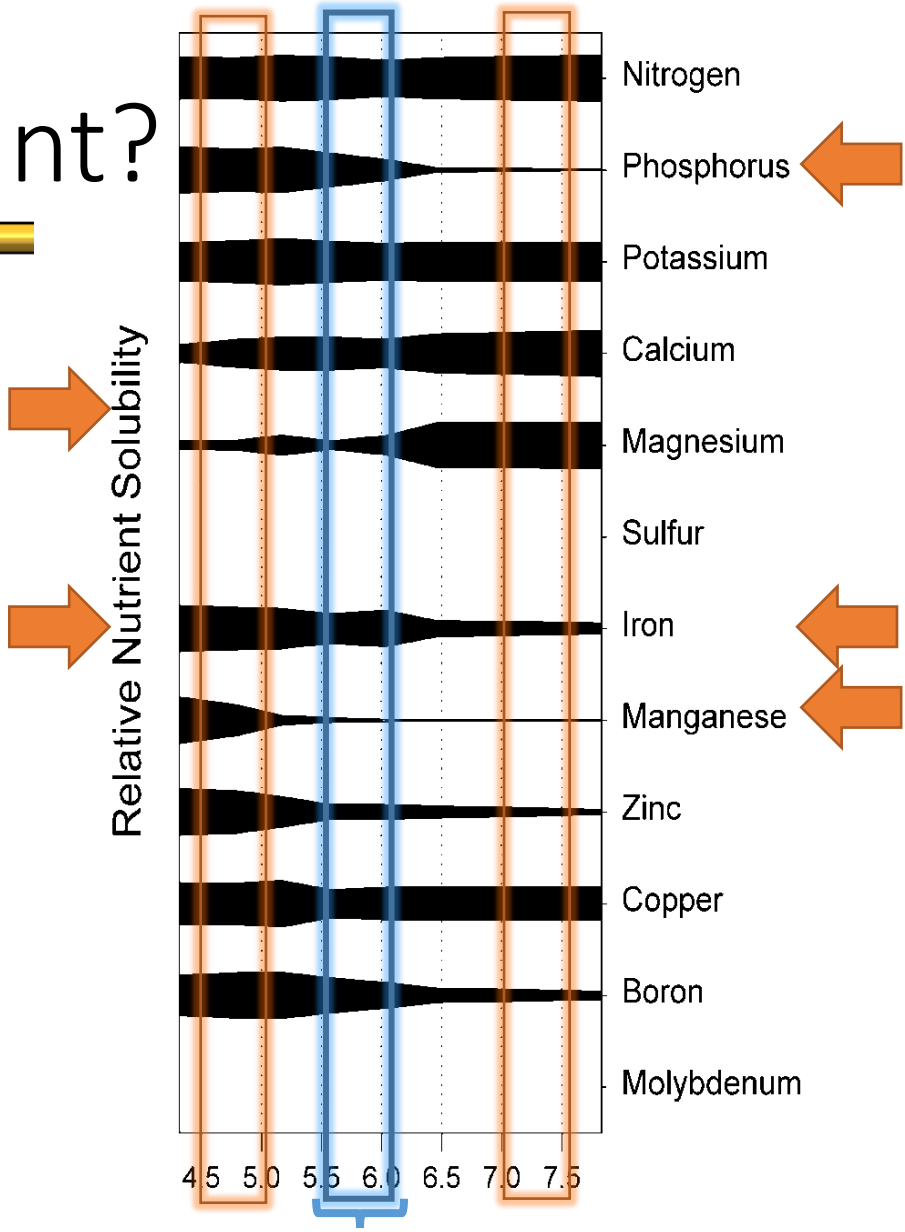




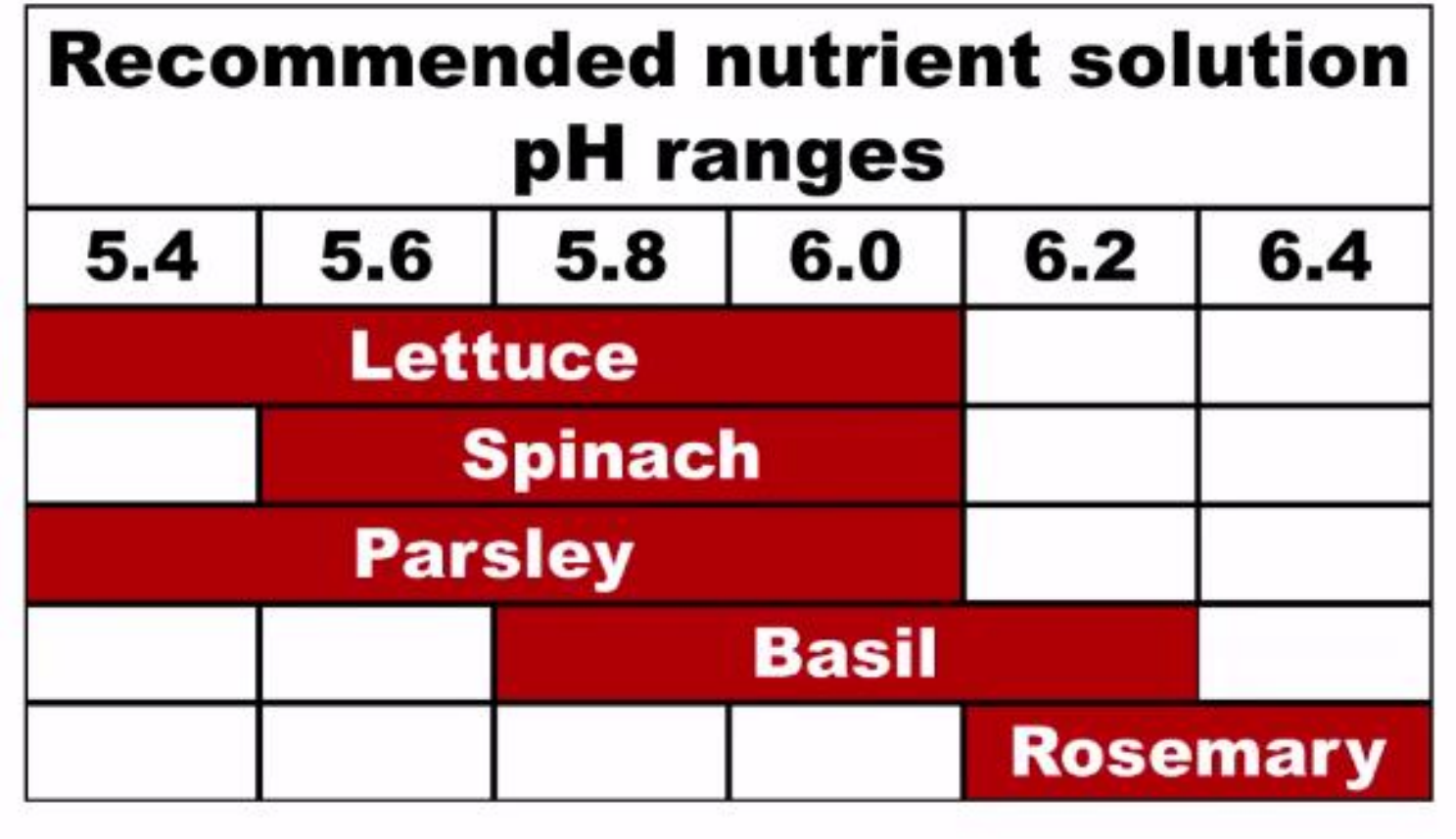
Why is pH important?

- Solubility (availability) of nutrients.

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



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)

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 salts exist as ions in water).

More dissolved nutrients=More electricity flow!

=Higher EC

TOO MUCH CAN BE TOXIC TO PLANTS

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

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^-

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

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.
PO Box 3310
Dublin, OH 43016
Testing Lab: 1-877-467-8522

Made in the U.S.A.

050112

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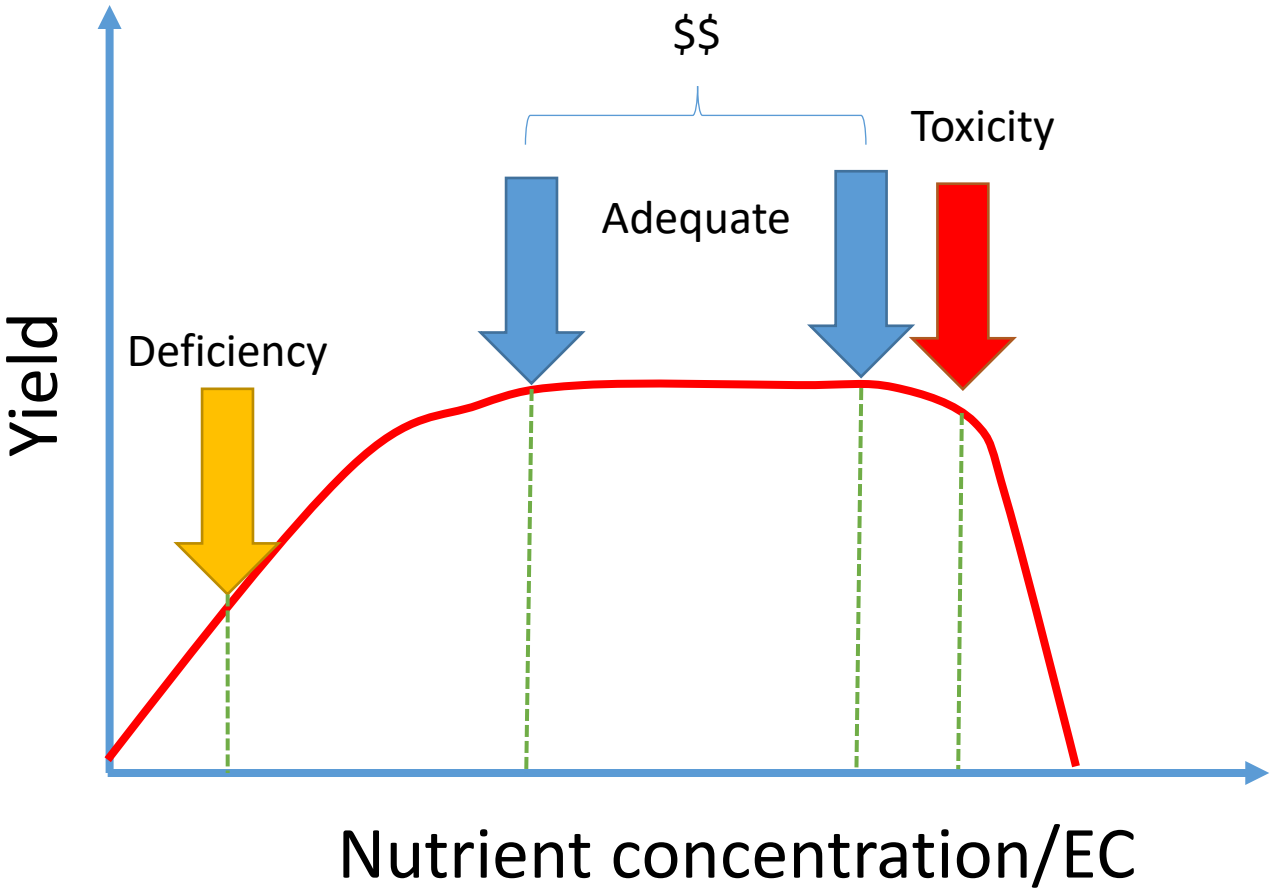
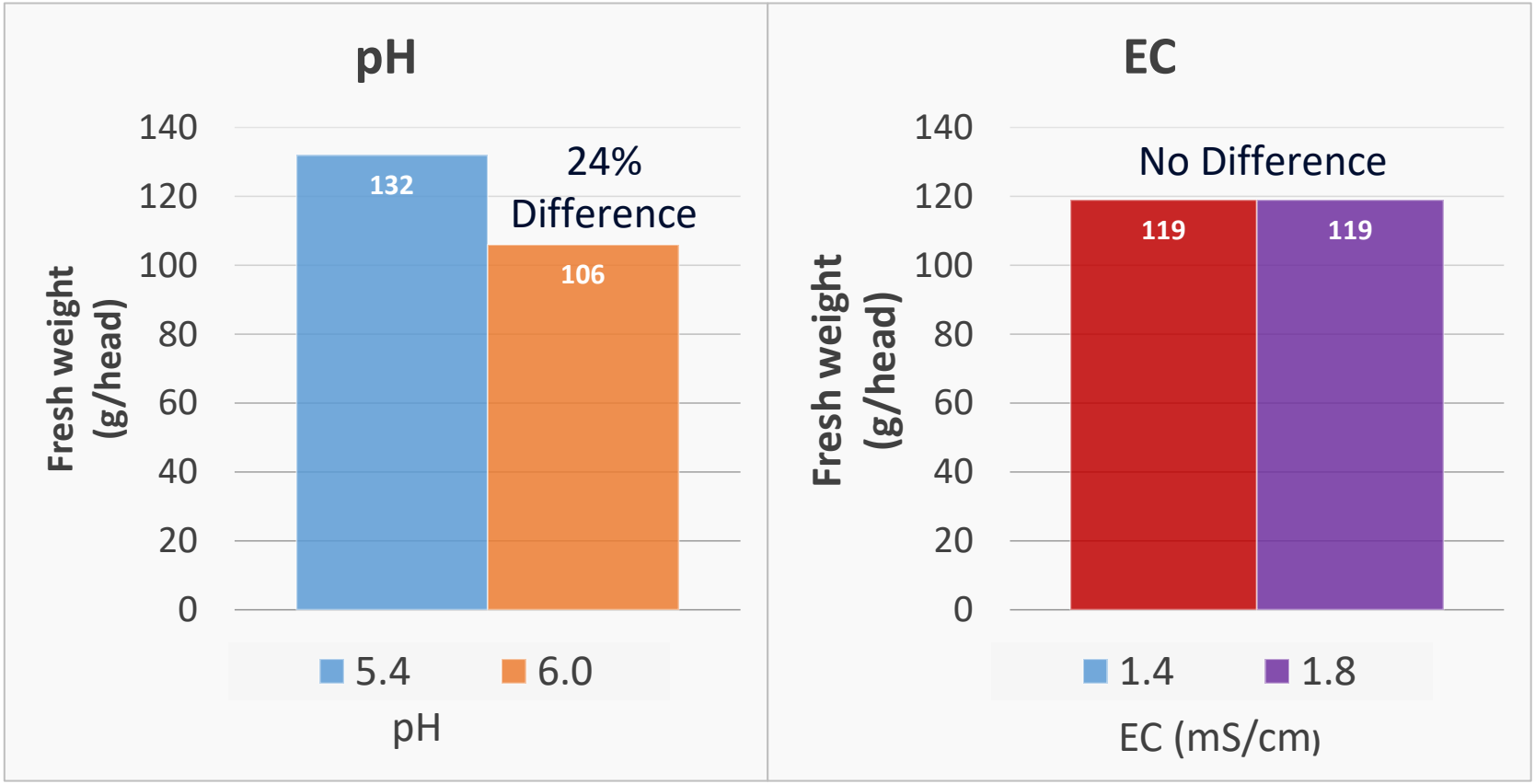
200	1.9	12.9	25.7	1.26
300	2.9	19.3	38.6	1.89

More is not better



Effect of pH and EC on hydroponic lettuce



(Adapted from Hansen et al., 2009; n=112)

Dissolved oxygen

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 ≥ 6 ppm

Temperature affects how much oxygen is held by water

↑ Temperature=↓ oxygen solubility

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

The solution temperature can affect plant health directly and indirectly.

Crop nutrient requirements

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

	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

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

Alkalinity

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=higher amounts of acid needed to change the pH.
- Low alkalinity=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

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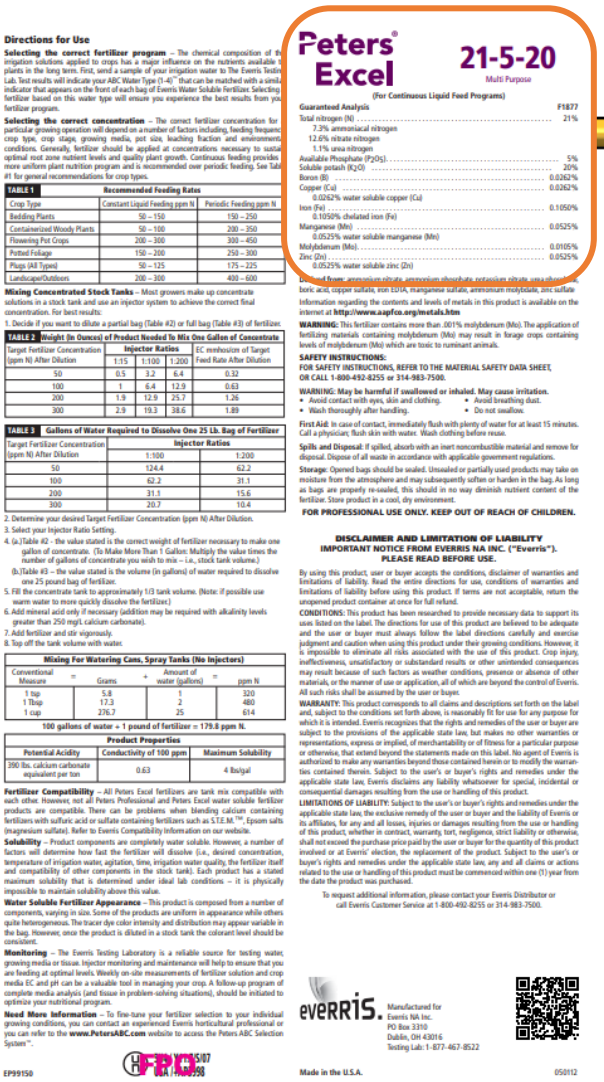

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Potted Foliage	150 – 200	250 – 300
Plugs (All Types)	50 – 125	175 – 225
Landscape/Outdoors	200 – 300	400 – 600

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:

1. Decide if you want to dilute a partial bag (Table #2) or full bag (Table #3) of fertilizer.

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

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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, phosphoric 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.
- Wash thoroughly after handling.
- Avoid breathing dust.
- 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.

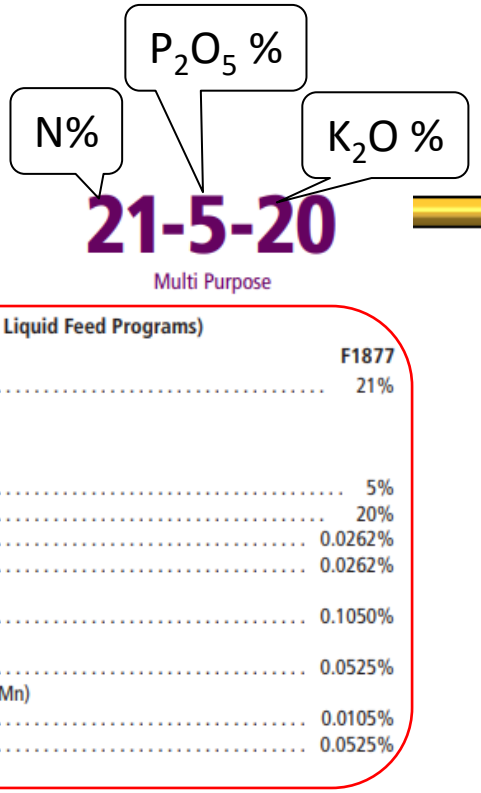
WARRANTY: This product corresponds to all claims and descriptions set forth on the label and, subject to the conditions set forth above, is reasonably fit for use for any purpose for which it is intended. Everris recognizes that the rights and remedies of the user or buyer are subject to the provisions 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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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

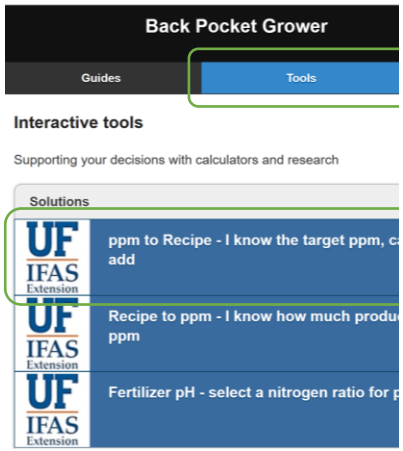
To convert grams (g) to ounces: gram x 0.035274

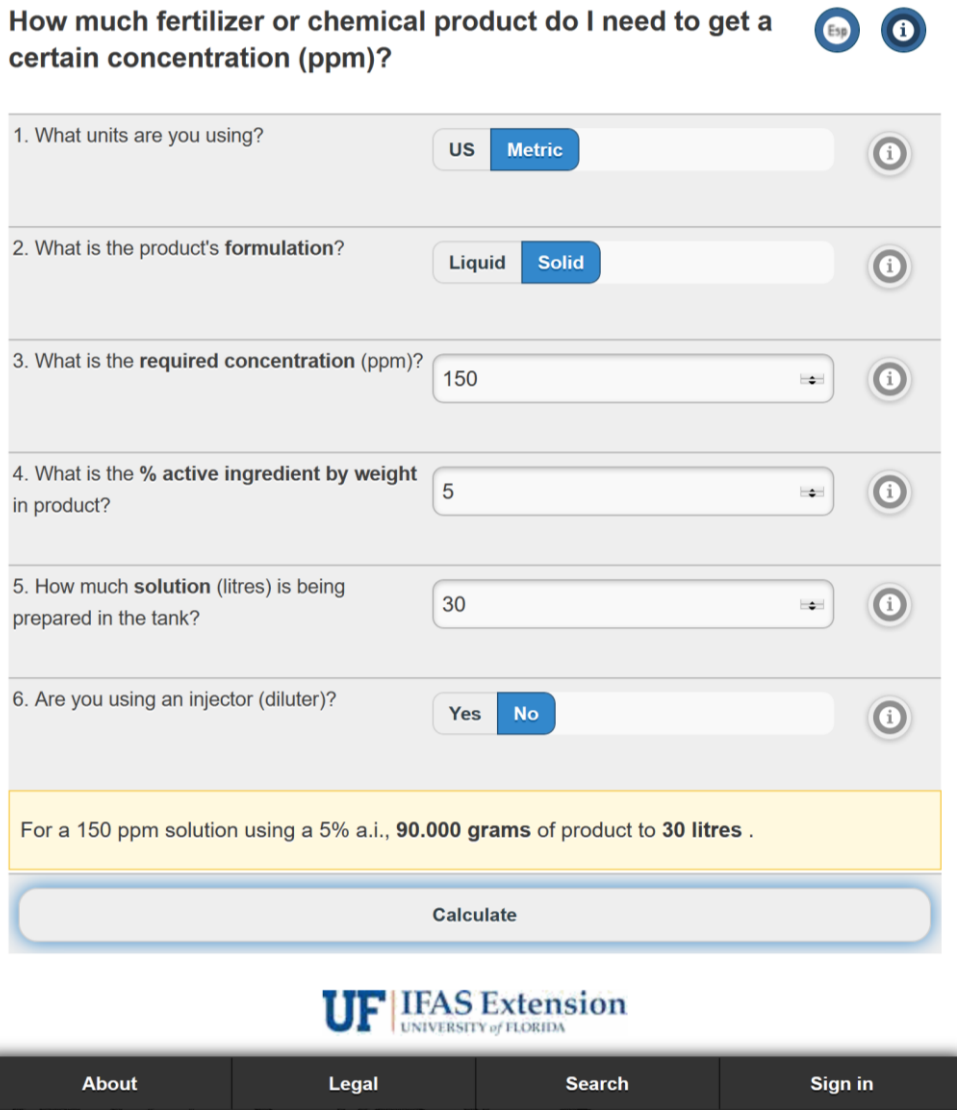
To convert liters (L) to gallons US: liters x 0.26417

Refer to the calculation handout for the 2 bag system.

Online calculators

www.backpocketgr





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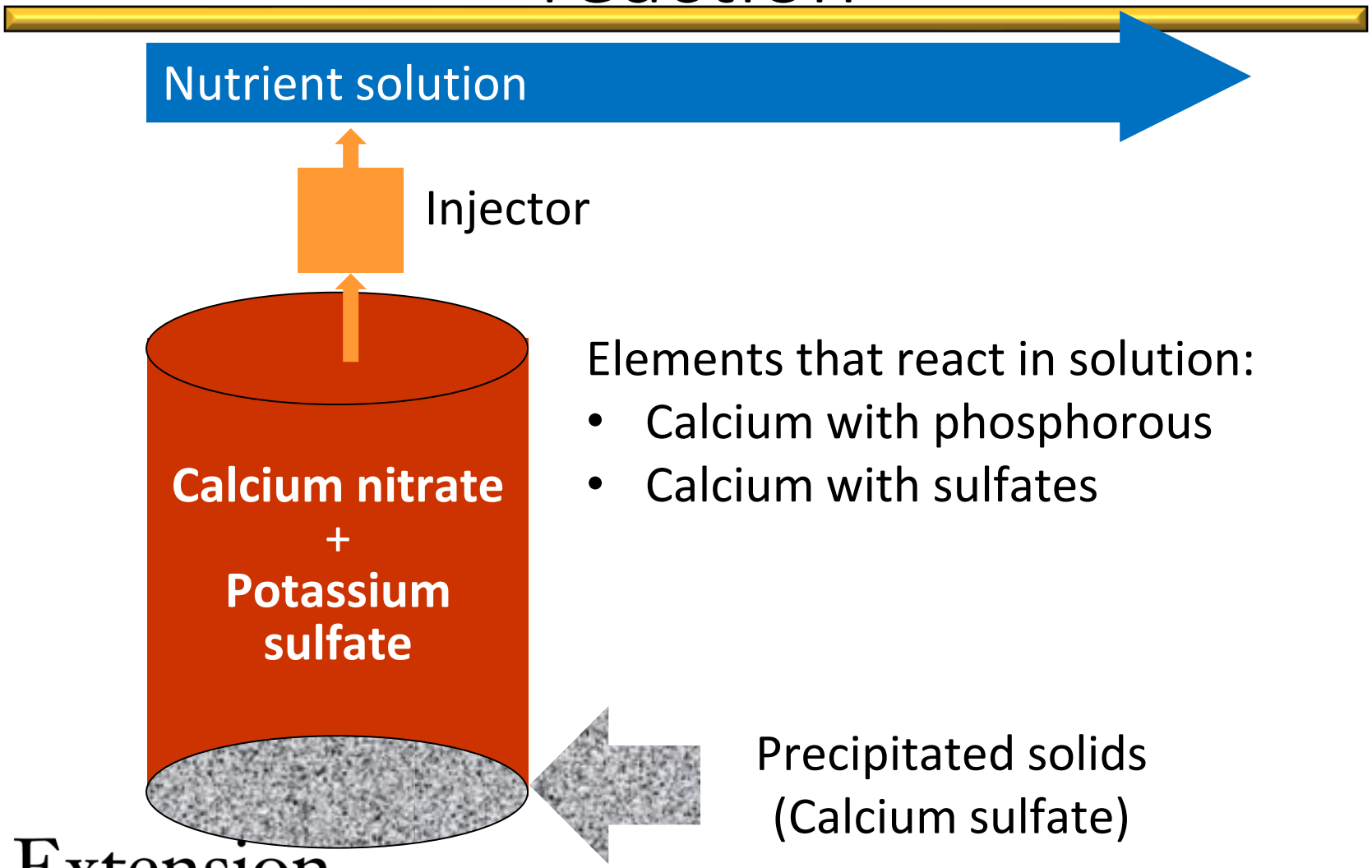
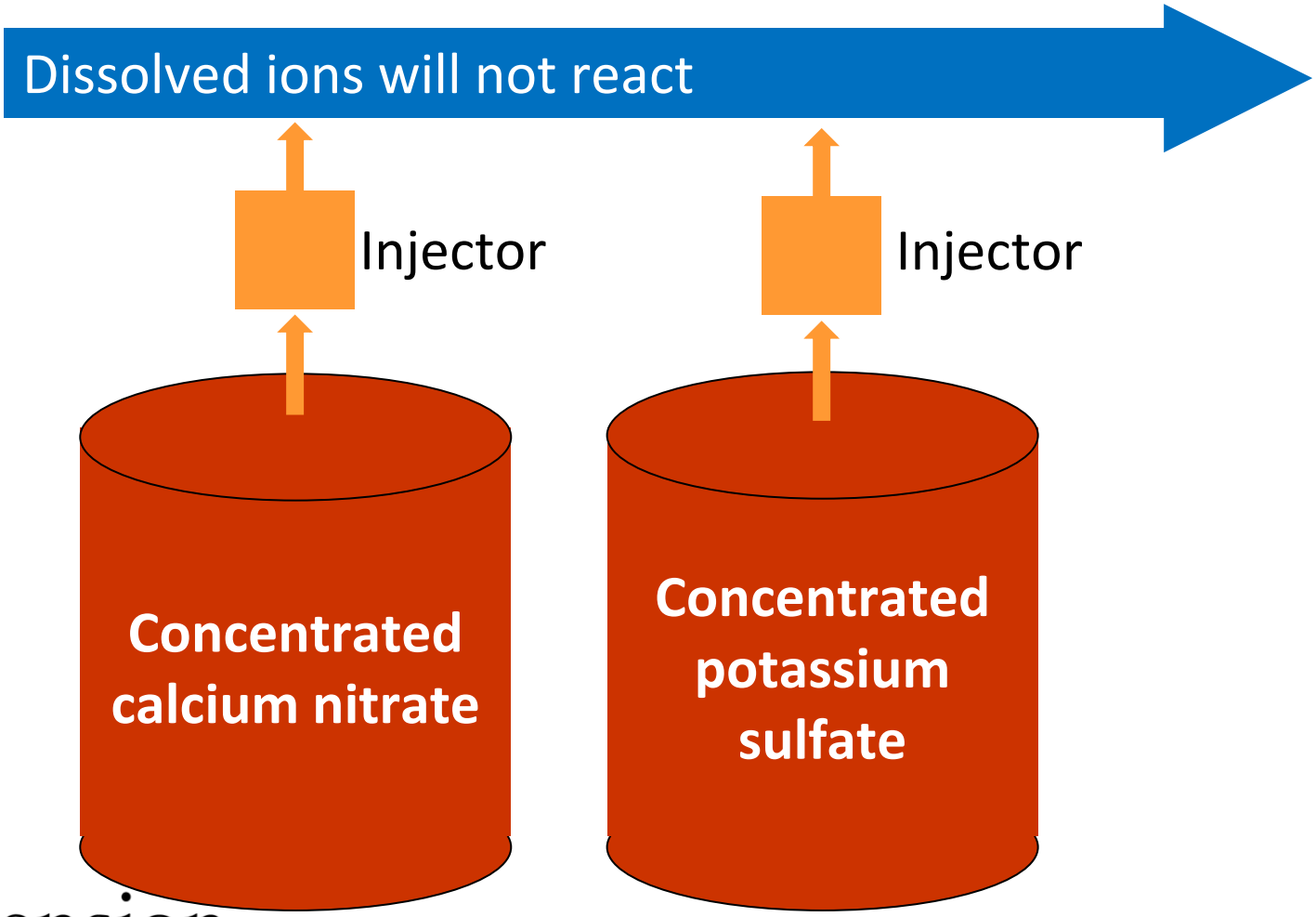
Fertilizer Incompatibility: Salt reaction



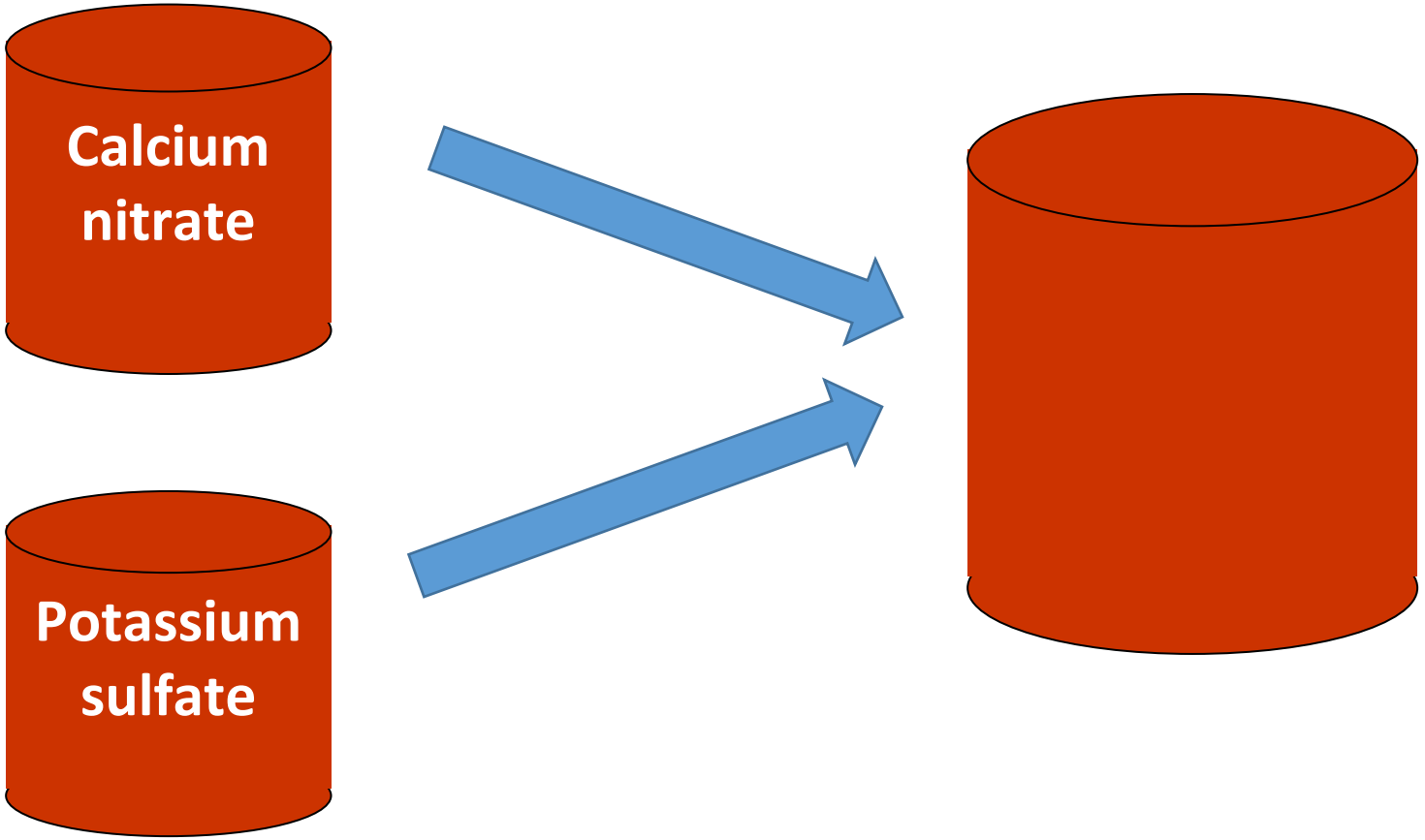
Elements that react in solution:

- Calcium with phosphorous
- Calcium with sulfates

Option 1: Separate incompatible salts in different concentrated tanks



Option 2: Dissolve fertilizers separately then mix them



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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	Required ppm	Provided by fertilizers
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

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

Element	Required ppm	Provided by fertilizers
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

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

Element	Required ppm	Provided by fertilizers
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

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

Element	Required ppm	Provided by fertilizers
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

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

1. Introduction
2. Factors that affect nutrient solutions
   - Water quality
   - pH
   - Electrical conductivity (EC)
   - Dissolved oxygen (temperature)
   - Crop requirements by growth stage
   - Water alkalinity (hardness)
3. Preparing nutrient solutions
4. Monitoring nutrient solutions
5. Organic fertilizers and aquaponics

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 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 (0ver 25% of the total nitrogen is from nitrates)
  - Potassium hydroxide
- Avoid using calcium carbonate (limestone) because it has low solubility.

Lowering the pH

Chemical	Notes
Mineral and organic acids	Cost $$: Cítrico > Fosfórico > Nítrico > Sulfúrico Safety: Cítrico > Fosfórico ≈ Sulfúrico > Nítrico Consider that some will provide additional nutrients.
Iron sulfate (for potted plants)	Can cause iron toxicity in plants, especially if the water contacts the leaves. It will precipitate and cause clogging.
Elemental sulfur (for potted plants)	Slow reaction and its solubility depends on the source of the product.

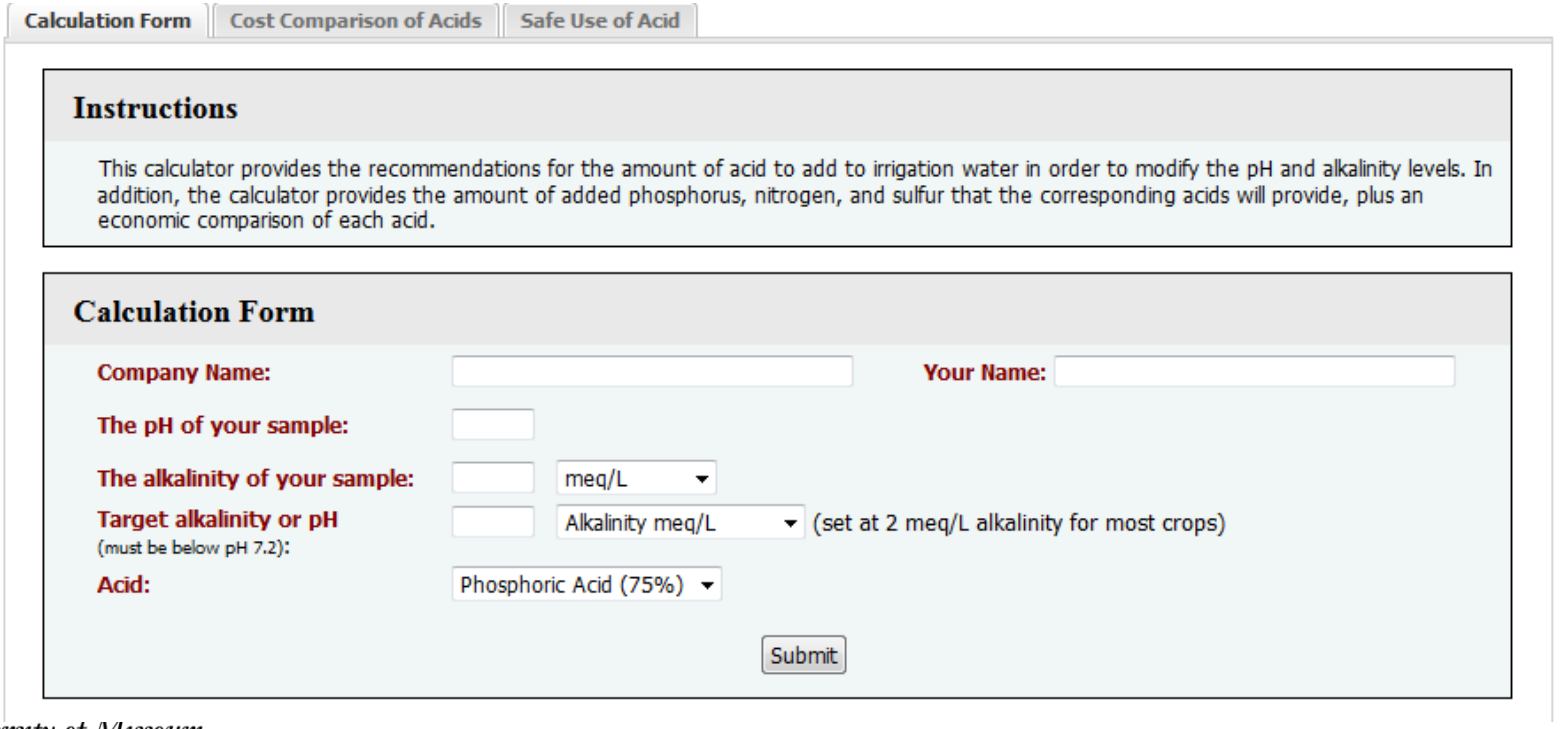
How much acid you need?
Depends on the alkalinity of the nutrient solution.

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

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

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Fotos: Hannah instruments

Proper care for meters

Foto: 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

Needed meters

Combo meters

Parameter	NFT & Dutch Bucket	DWC
pH	✓	✓
Electric conductivity (EC)	✓	✓
Temperature	✓	✓
Dissolved oxygen (DO)	⊘	✓

Topics

1. Introduction
2. Factors that affect nutrient solutions
   - Water quality
   - pH
   - Electrical conductivity (EC)
   - Dissolved oxygen (temperature)
   - Crop requirements by growth stage
   - Water alkalinity (hardness)
3. Preparing nutrient solutions
4. Monitoring nutrient solutions
5. Organic fertilizers and aquaponics

Organic Fertilizers

3-1-1

GUARANTEED ANALYSIS

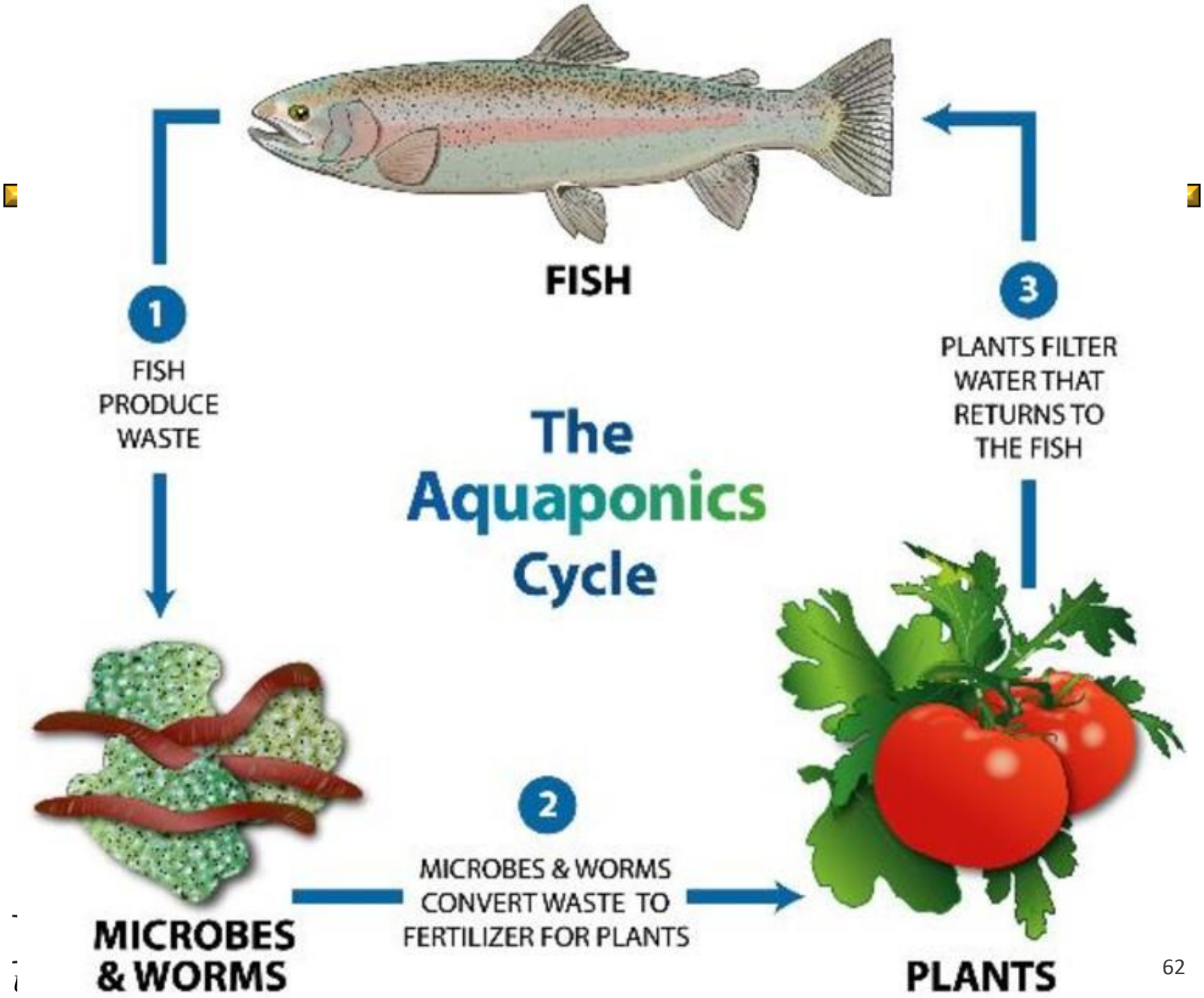
Total Nitrogen (N) 3%
2.55% Water Soluble Nitrogen
0.45% Water Insoluble Nitrogen

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

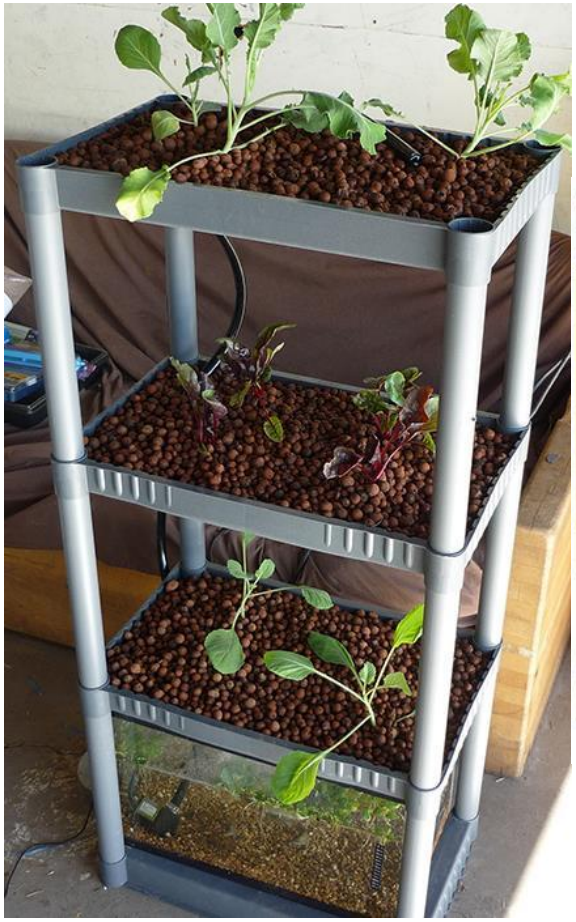
Soluble Potash (K_2O) 1%

Derived From: Fermented Oilseed Extract

10 lbs. per gallon at 68°F **F2358**


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

Coupled aquaponic systems



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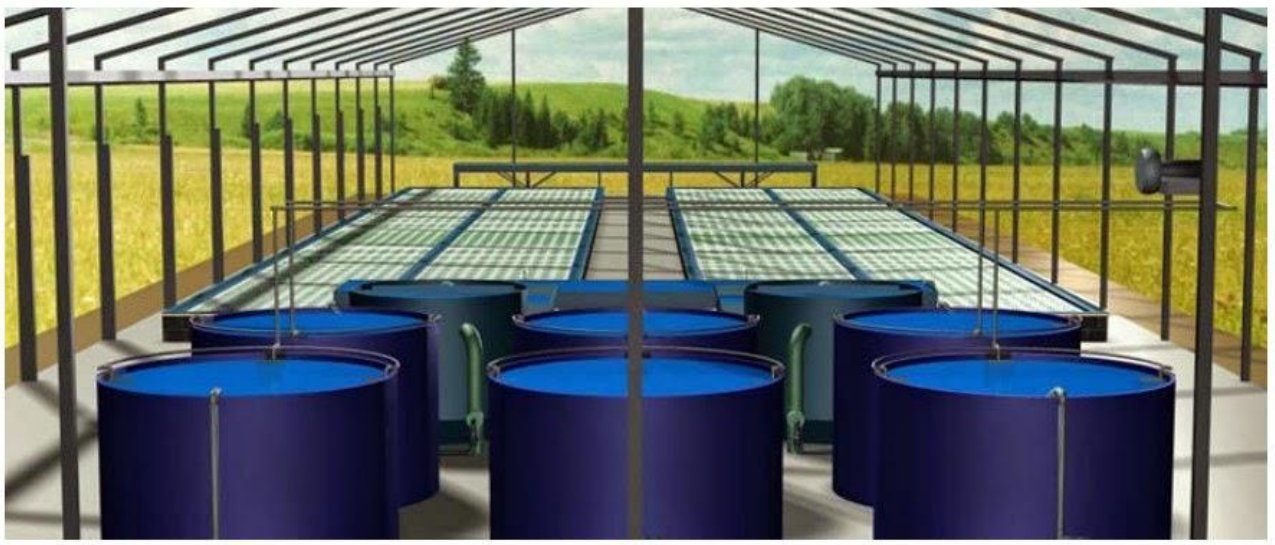

An aquaponics float system based on the UVI (University of the Virgin Islands) design.

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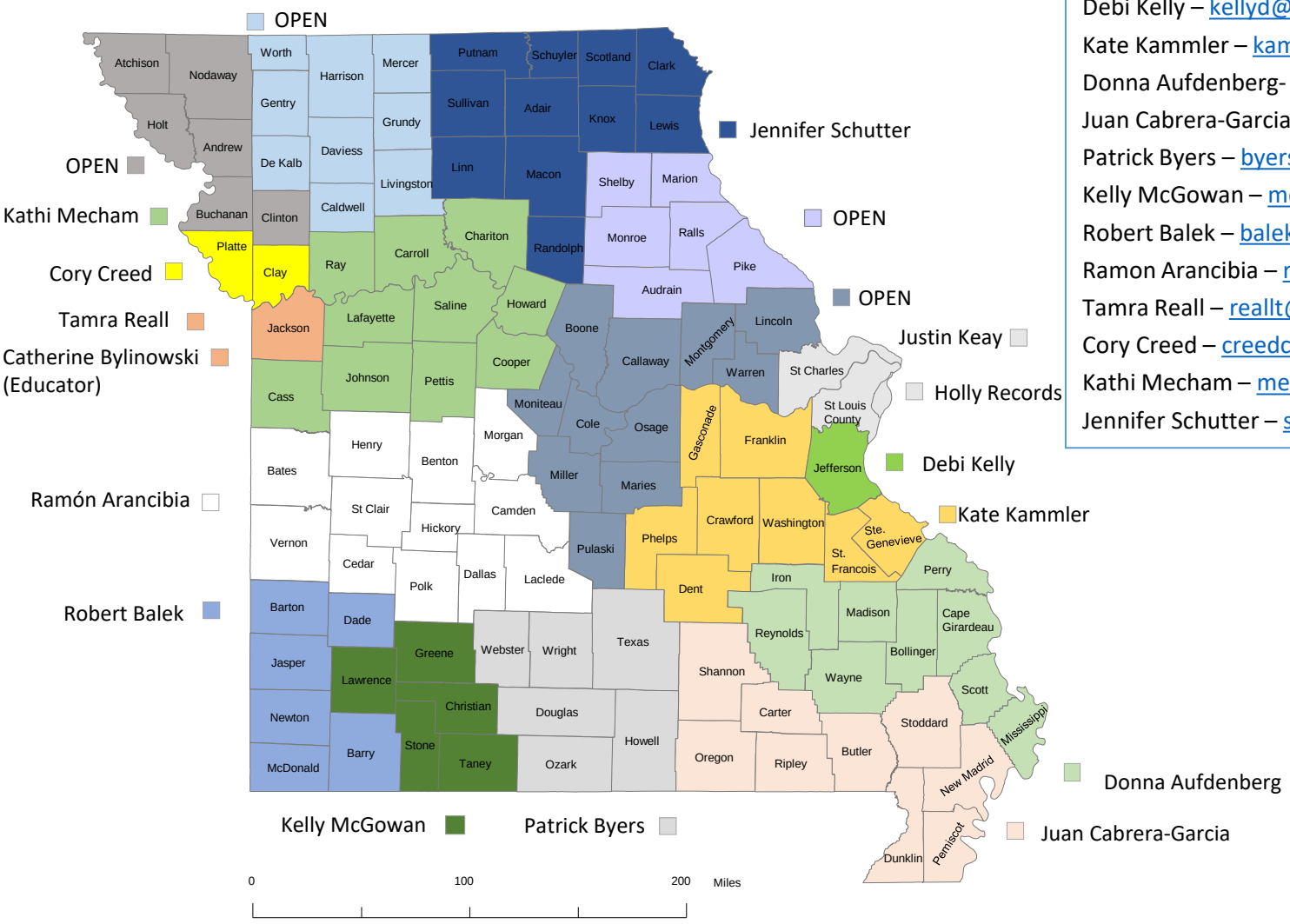

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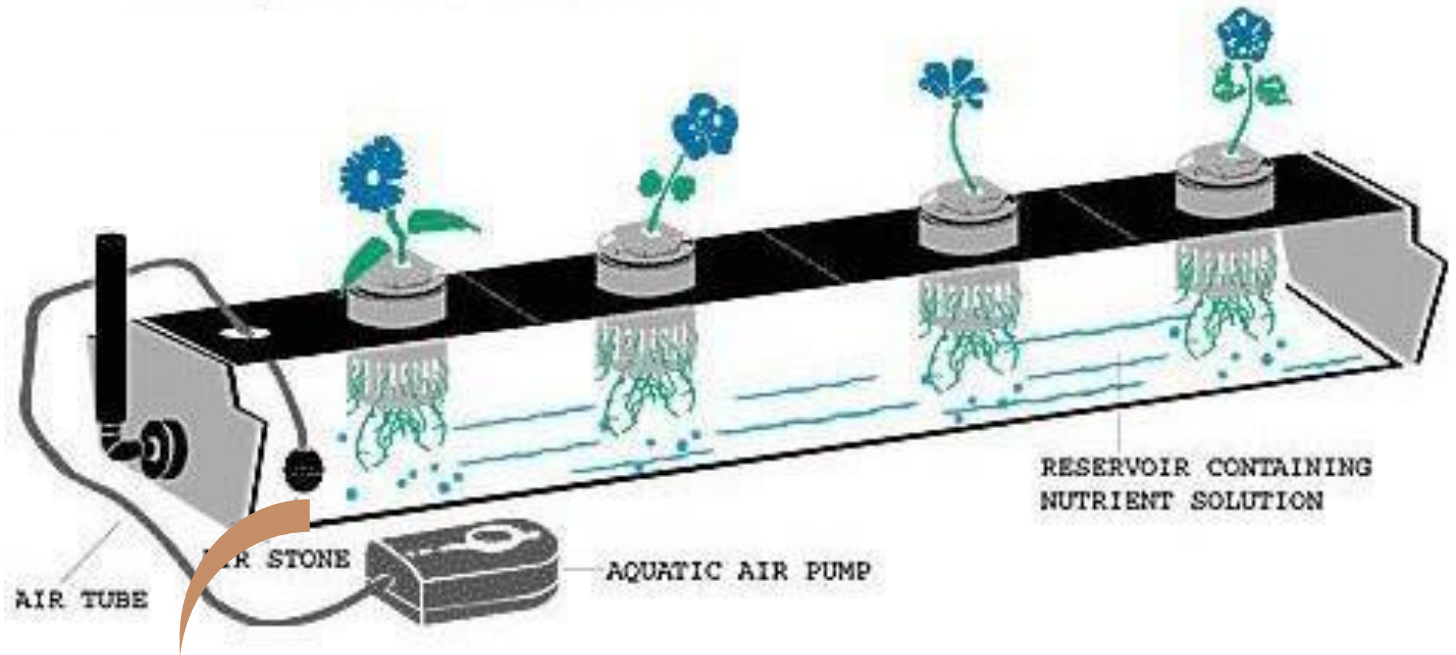
Optional Advanced nutrition and Aquaponic Slides

Advanced concepts

Factors that affect the nutrient solution

Plant's comfort zone!



- Water quality
- pH
- Electrical conductivity (EC)
- Nutrient requirements (for each crop and growth stage)
- Water alkalinity
- Dissolved oxygen

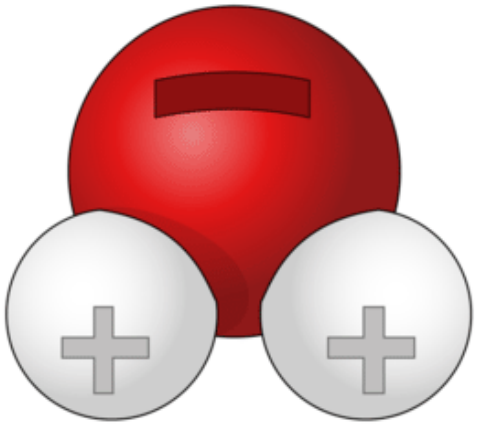
EMW-400 : Water Irrigation Suitability

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			

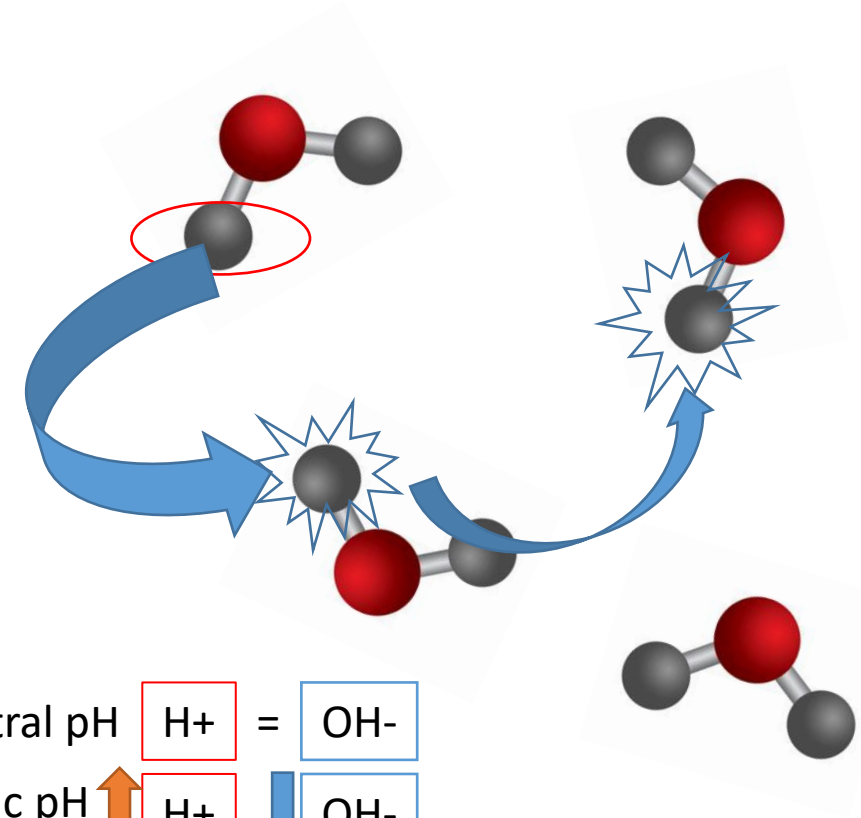
pH

Water

Water molecule



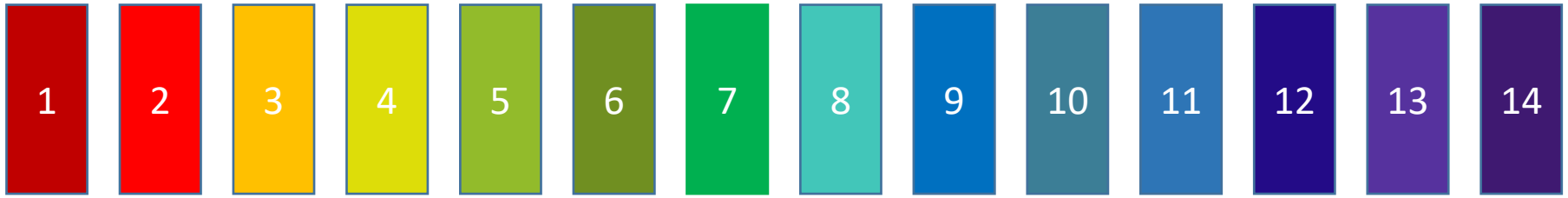
Oxygen (O)
Hydrogen (H)

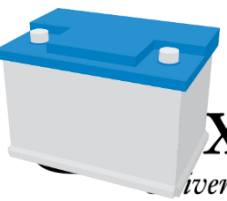


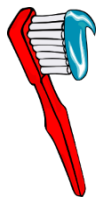
Neutral pH	H+	=	OH-
Acidic pH	H+		OH-
Basic pH	H+		OH-

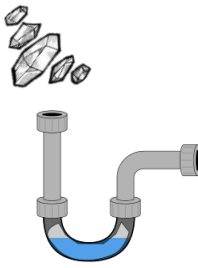
What is pH?

- 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.





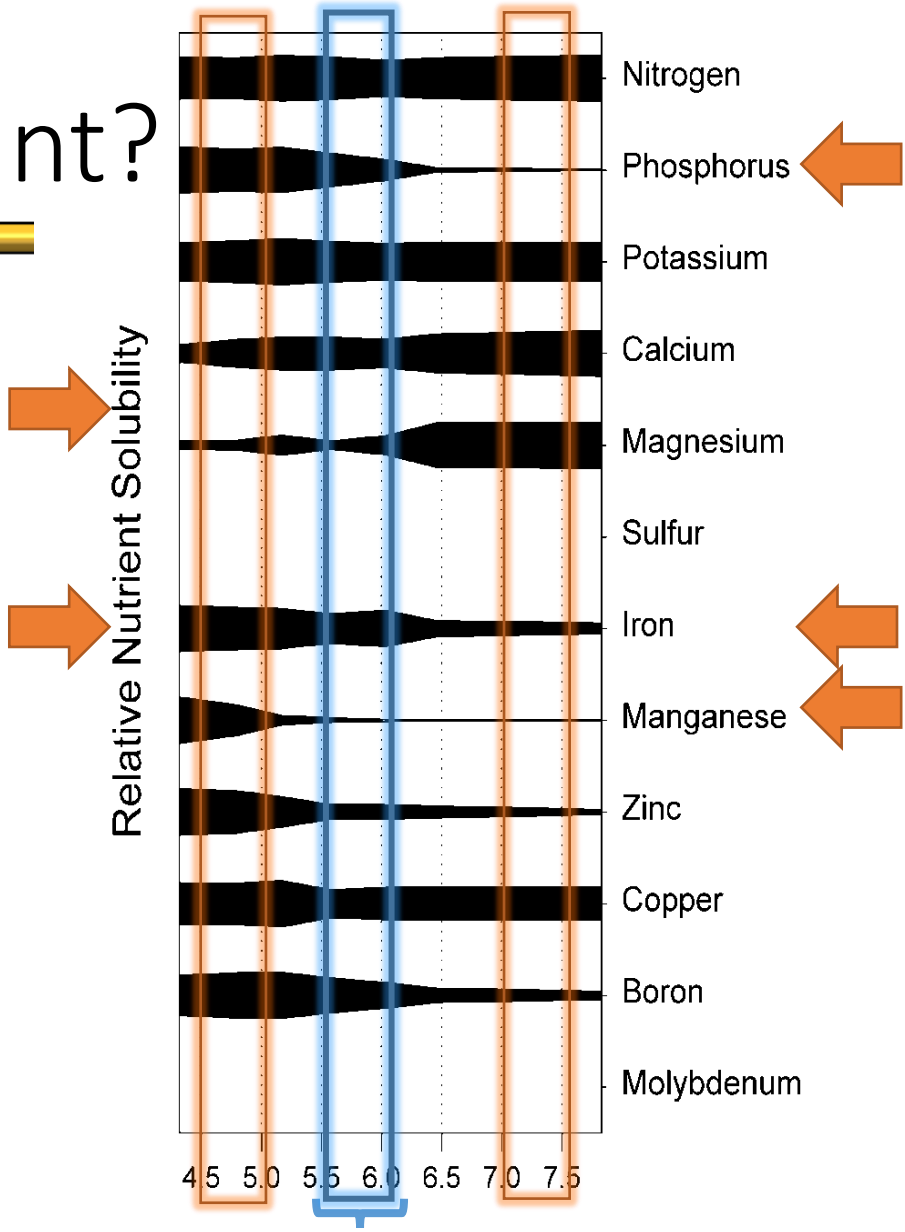




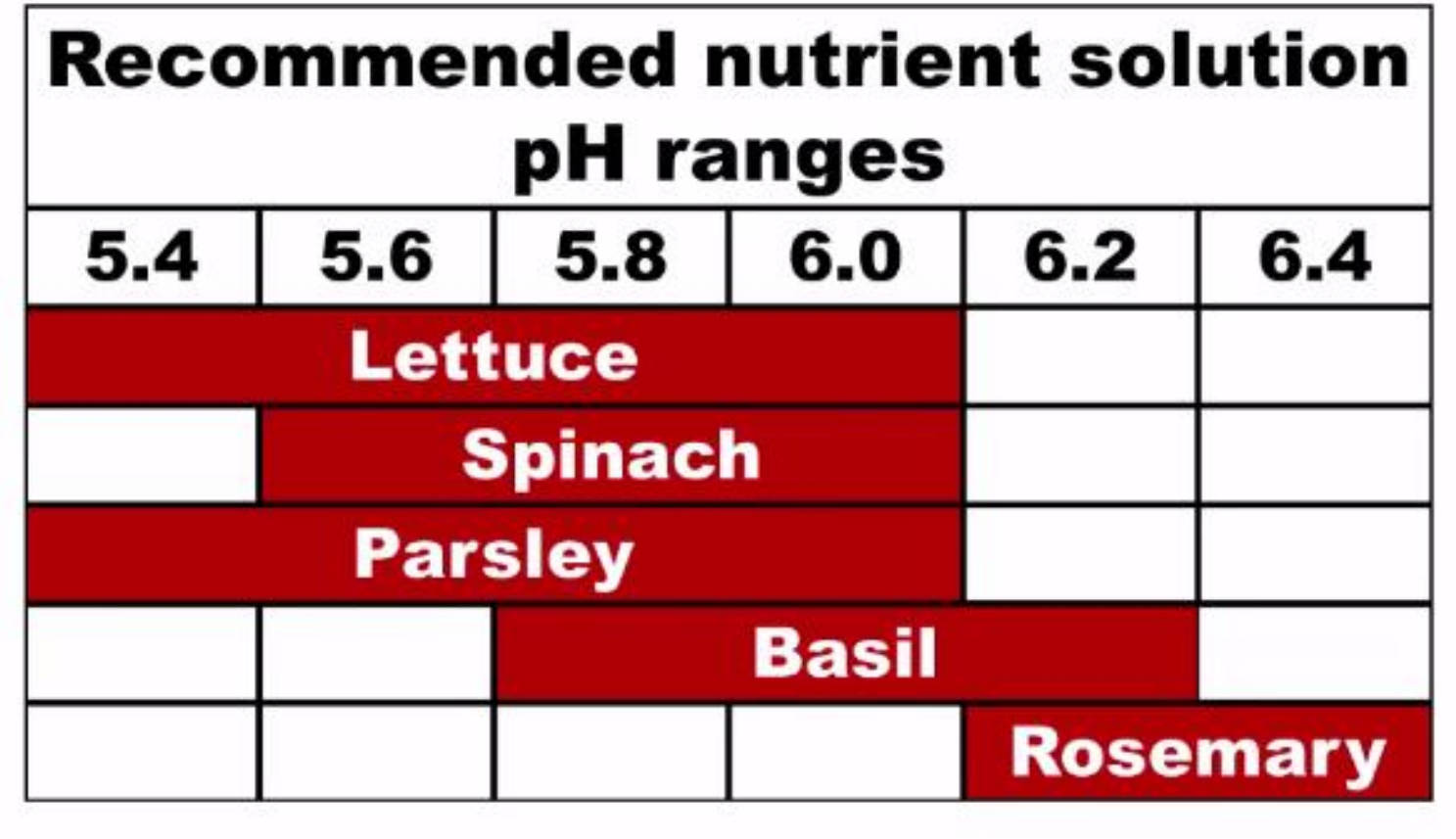
Why is pH important?

- Solubility (availability) of nutrients.

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



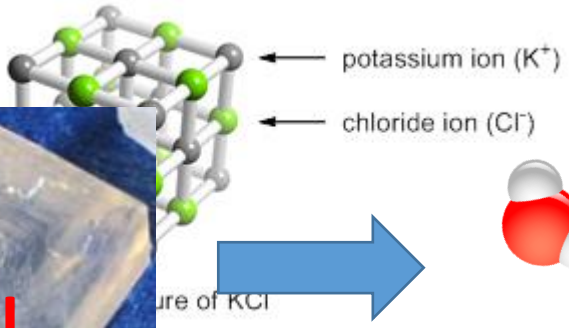
Optimum pH

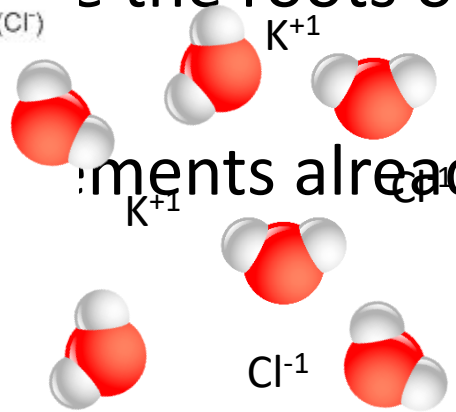

Recommended nutrient solution pH ranges
5.4
5.6
5.8
6.0
6.2
6.4
Lettuce
Spinach
Parsley
Basil
Rosemary

Electrical conductivity (EC)

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 in to their charged state or ions (+: cations and -: anions). $K^{+1} + Cl^{-1} \rightarrow KCl$
- This is importa… e the roots of plants t…
- The wa… ments already in solutio…





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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 salts exist as ions in water).

  More dissolved nutrients=More electricity flow!

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

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.

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

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

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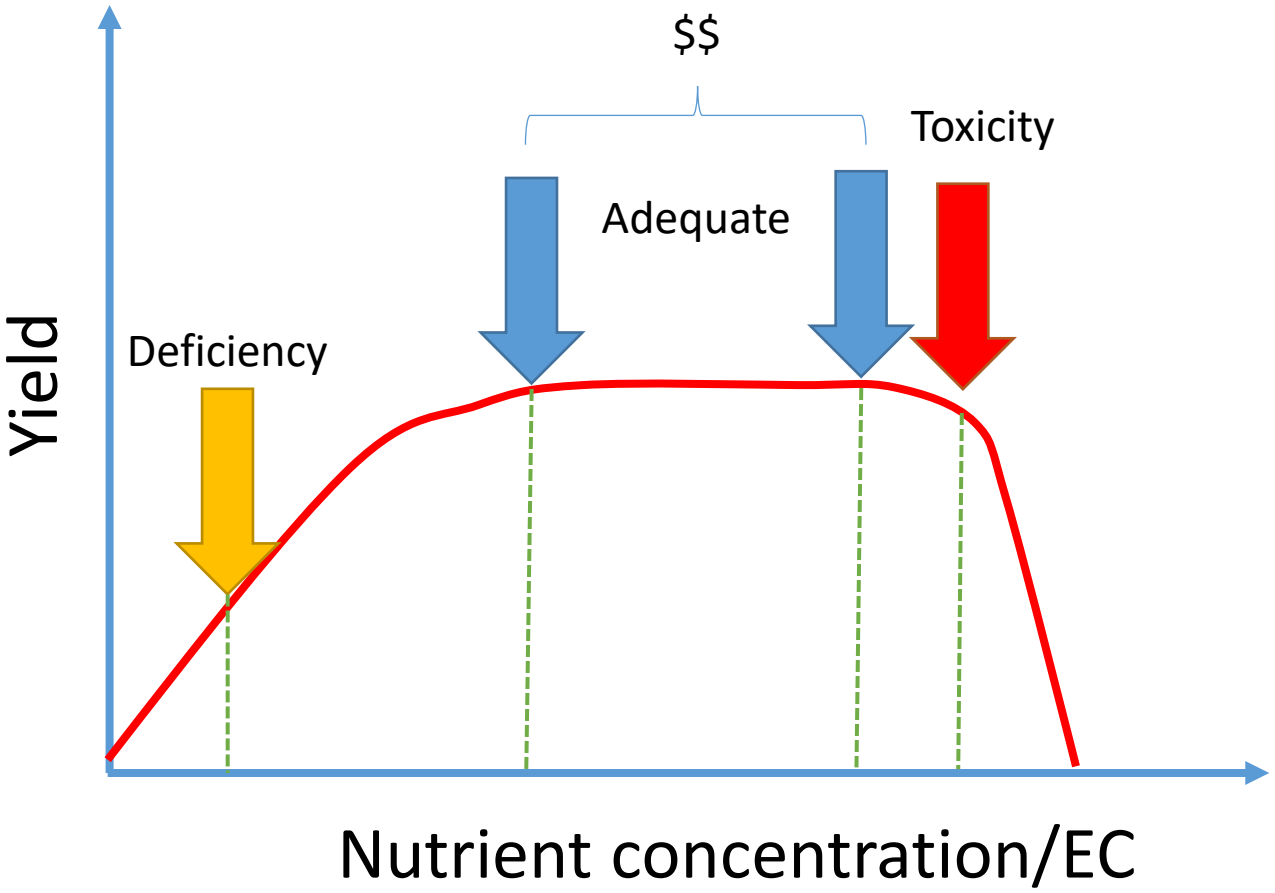
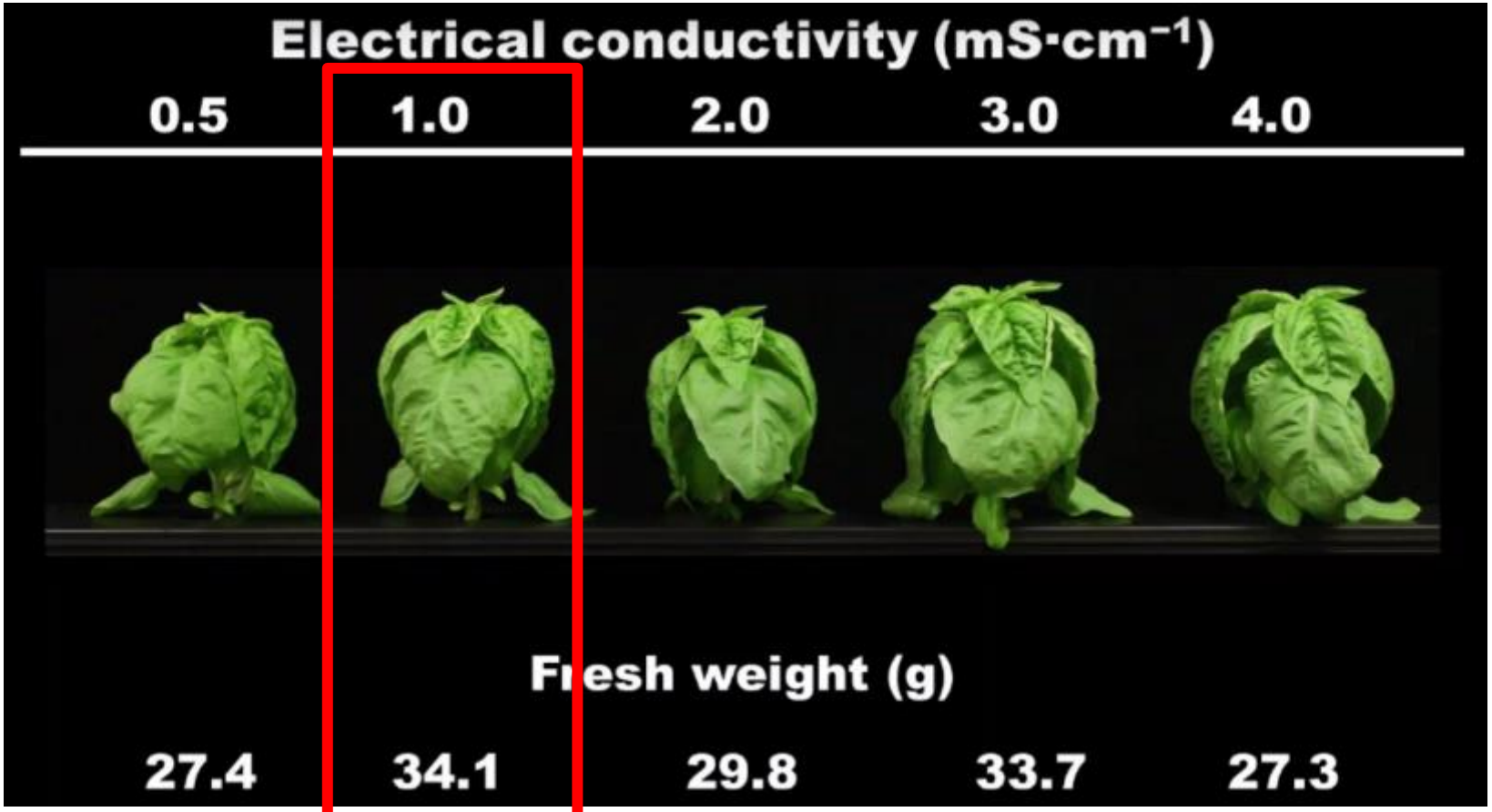
200	1.9	12.9	25.7	1.26
300	2.9	19.3	38.6	1.89

More is not better



Basil's response to different EC levels: More is not better

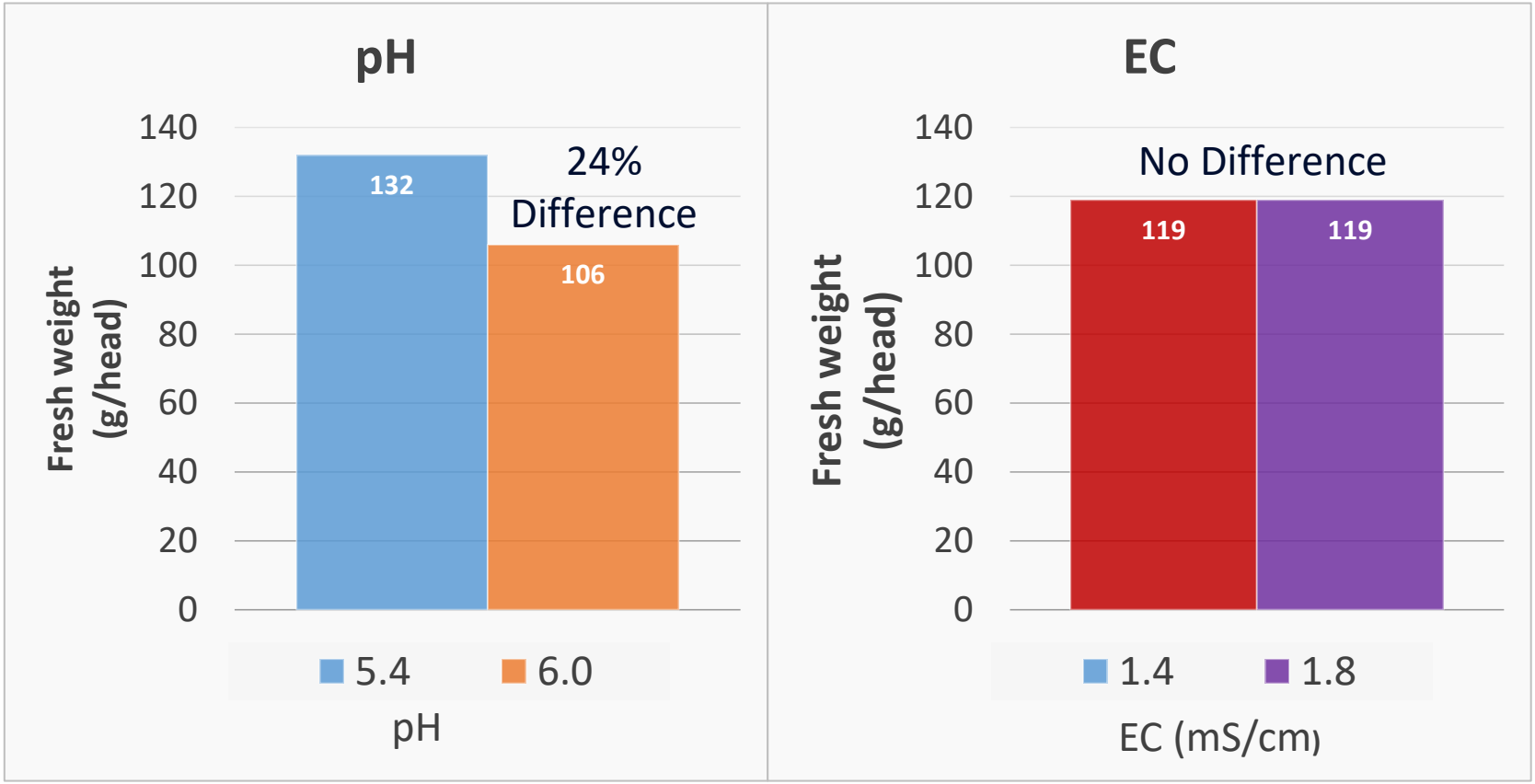


Source: Chris Currey, Iowa State Univ.

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

Effect of pH and EC on hydroponic lettuce



(Adapted from Hansen et al., 2009; n=112)

Dissolved oxygen

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 ≥ 6 ppm

Temperature affects how much oxygen is held by water

↑ Temperature=↓ oxygen solubility

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

The solution temperature can affect plant health directly and indirectly.

Crop nutrient requirements

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 (milligrams/liter)

Solids: 1 mg/kg (milligrams/kilograms)

1%: 1/100 = 10,000 ppm

- Recommendations for leafy greens given as ppm of nitrogen

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

	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

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

Alkalinity

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”
- The higher the alkalinity, higher amounts of acid needed to change the pH.

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

Alkalinity and pH management

- Water with high alkalinity needs a lot of acid to change the pH
- Low alkalinity: pH will fluctuate constantly forcing you to constantly monitor and adjust the pH

$$$

Topics

1. Introduction
2. Factors that affect nutrient solutions
   - Water quality
   - pH
   - Electrical conductivity (EC)
   - Dissolved oxygen (temperature)
   - Crop requirements by growth stage
   - Water alkalinity (hardness)
3. Preparing nutrient solutions
4. Monitoring nutrient solutions
5. Organic fertilizers and aquaponics

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

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

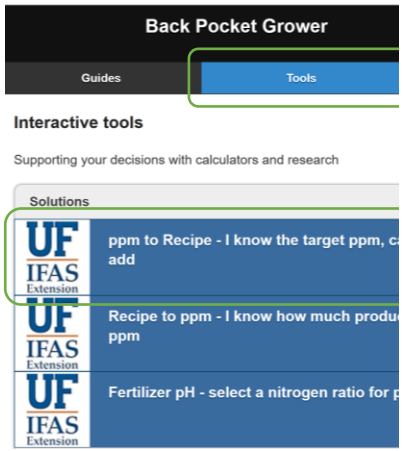
To convert grams (g) to ounces: gram x 0.035274

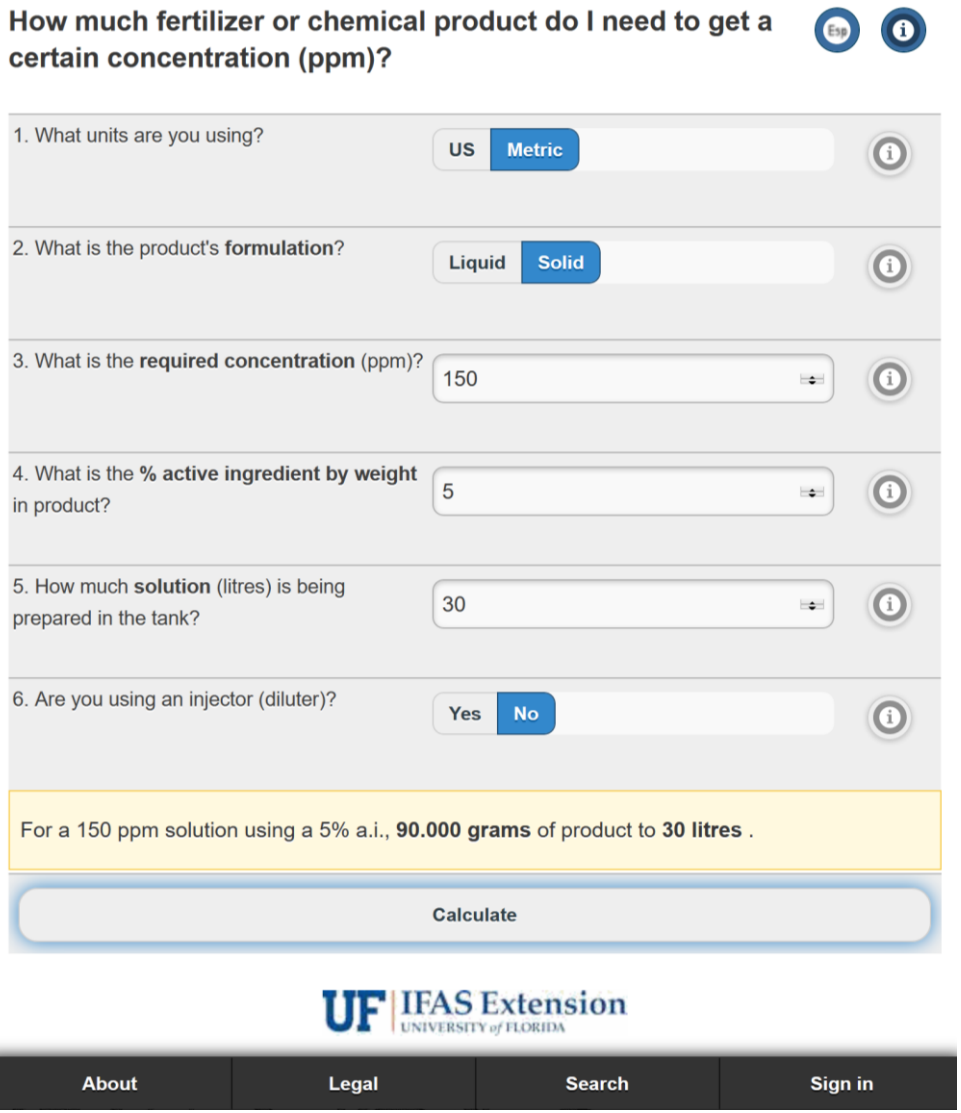
To convert liters (L) to gallons US: liters x 0.26417

Refer to the calculation handout for the 2 bag system.

Online calculators

www.backpocketgr





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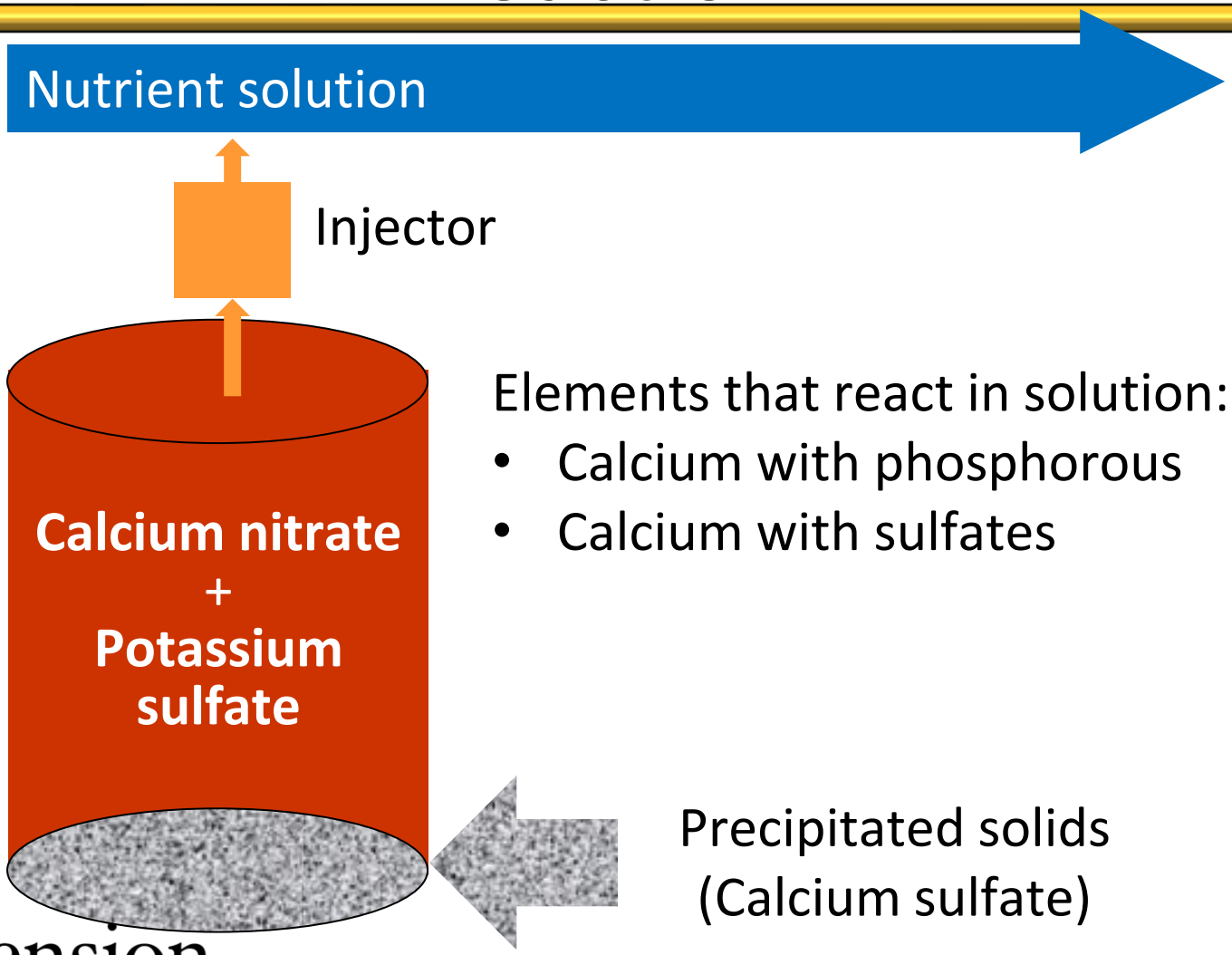
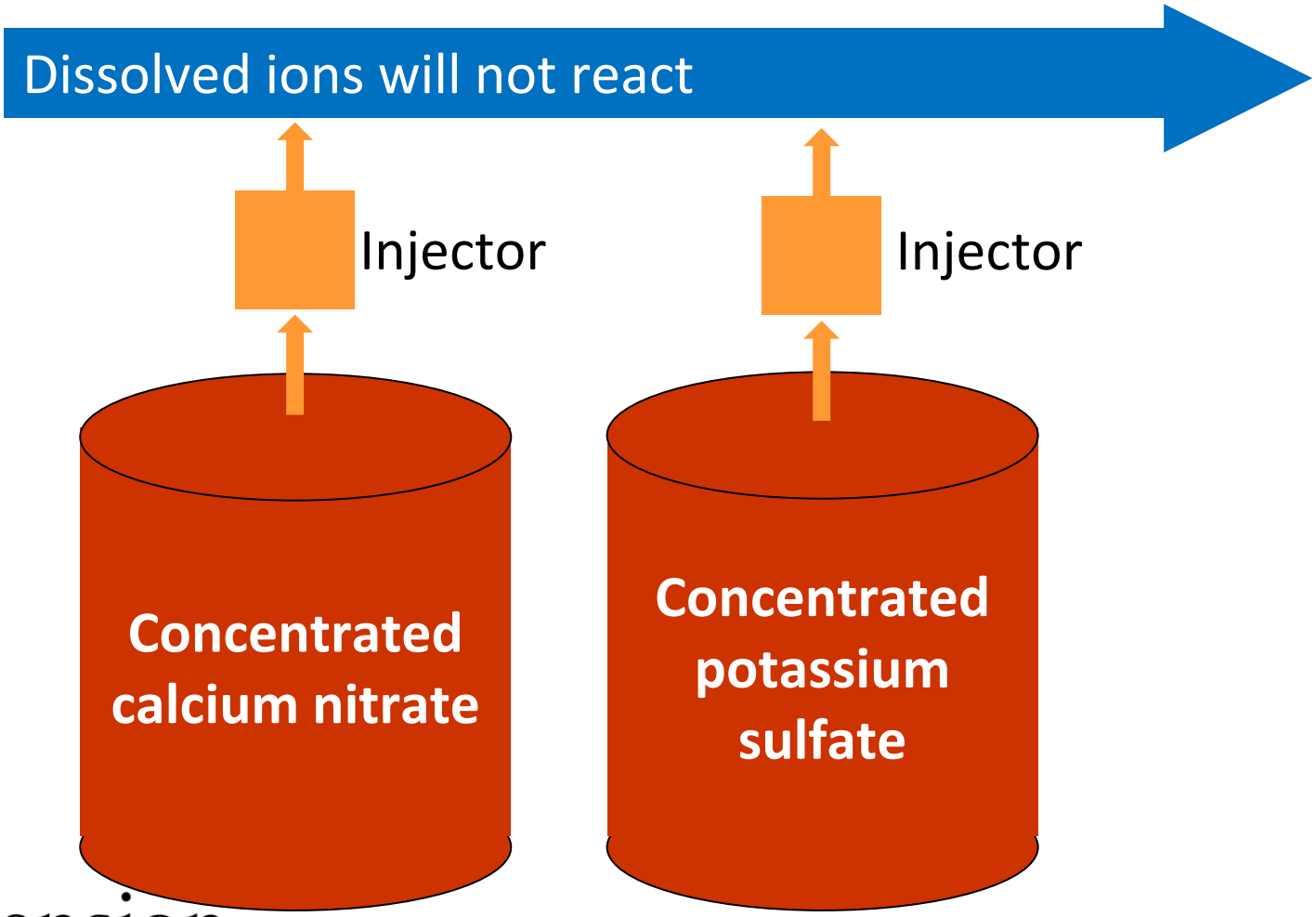
Fertilizer Incompatibility: Salt reaction



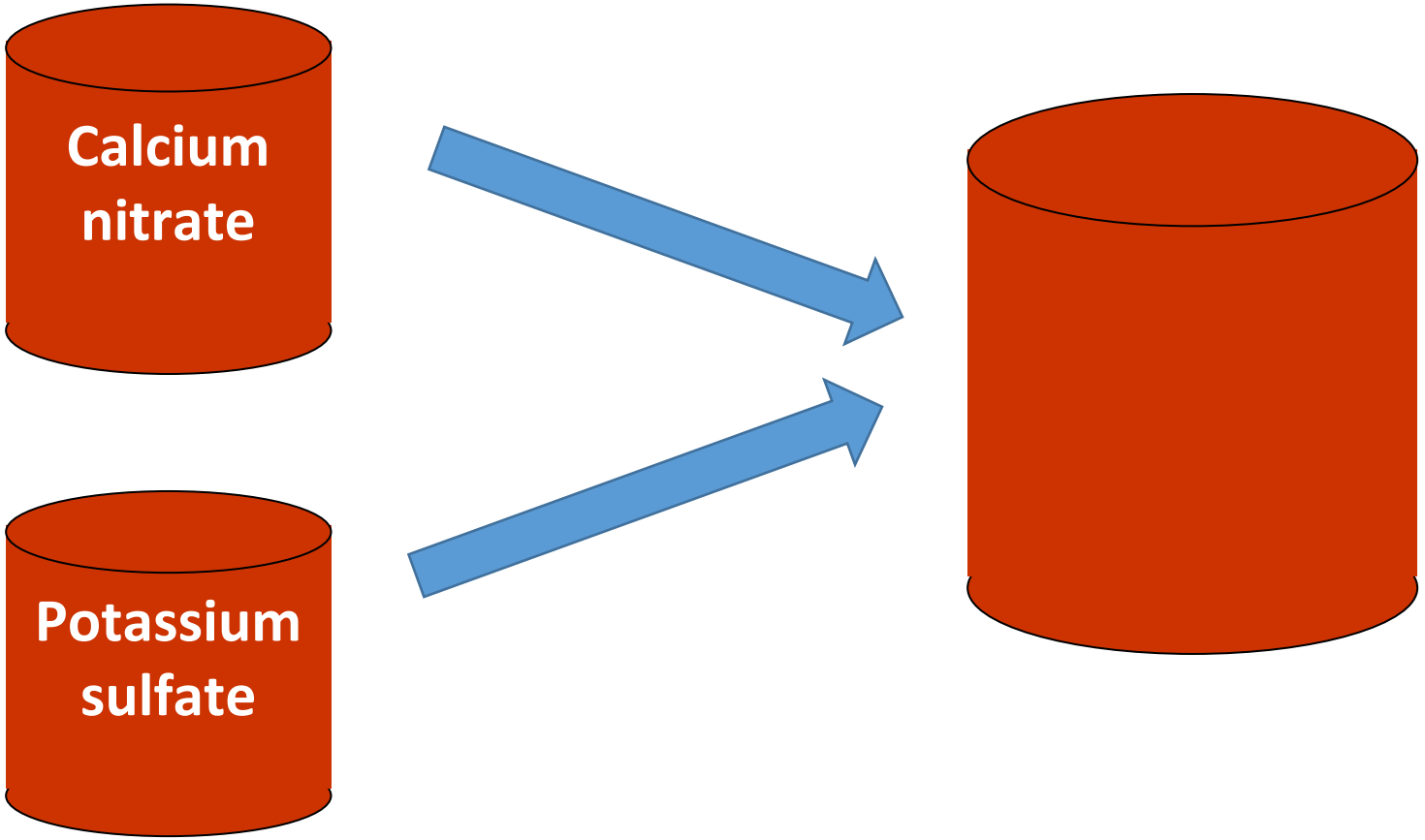
Elements that react in solution:

- Calcium with phosphorous
- Calcium with sulfates

Option 1: Separate incompatible salts in different concentrated tanks



Option 2: Dissolve fertilizers separately then mix them



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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	Required ppm	Provided by fertilizers
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

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

Element	Required ppm	Provided by fertilizers
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

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

Element	Required ppm	Provided by fertilizers
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

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

Element	Required ppm	Provided by fertilizers
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

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

Increasing the pH

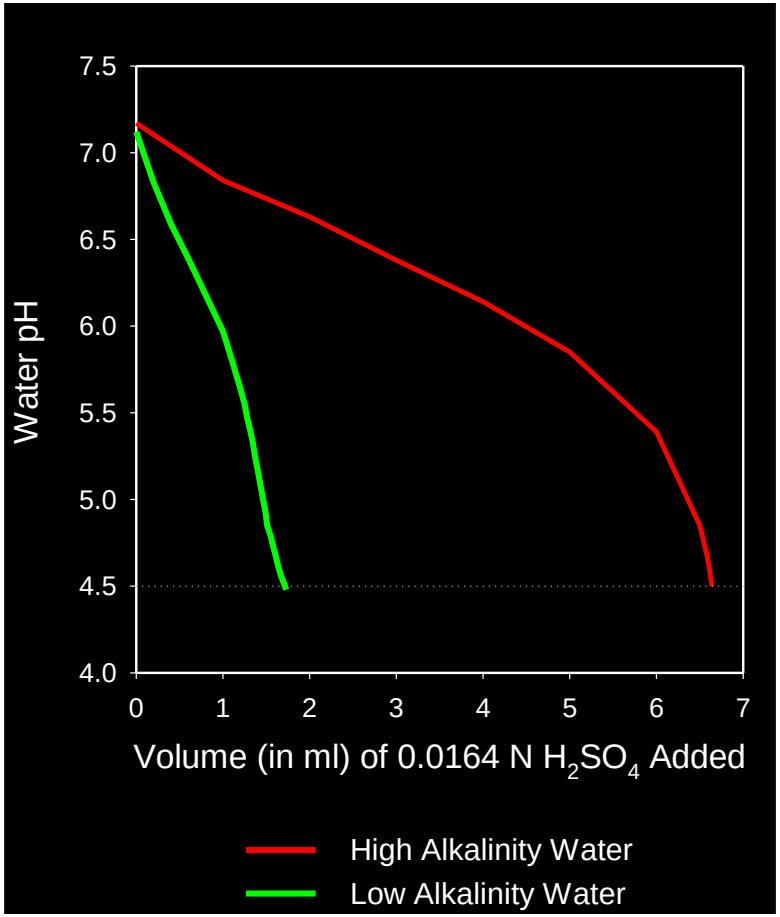
- Use:
  - Potassium bicarbonate
  - Fertilizers with high nitrate concentration (0ver 25% of the total nitrogen is from nitrates)
  - Potassium hydroxide
- Avoid using calcium carbonate because it has low solubility.

Lowering the pH

Chemical	Notes
Mineral and organic acids	Cost $$: Cítrico > Fosfórico > Nítrico > Sulfúrico Safety: Cítrico > Fosfórico ≈ Sulfúrico > Nítrico Consider that some will provide additional nutrients.
Iron sulfate (for potted plants)	Can cause iron toxicity in plants, especially if the water contacts the leaves. It will precipitate and cause clogging.
Elemental sulfur (for potted plants)	Slow reaction and its solubility depends on the source of the product.

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

Why is alkalinity important?

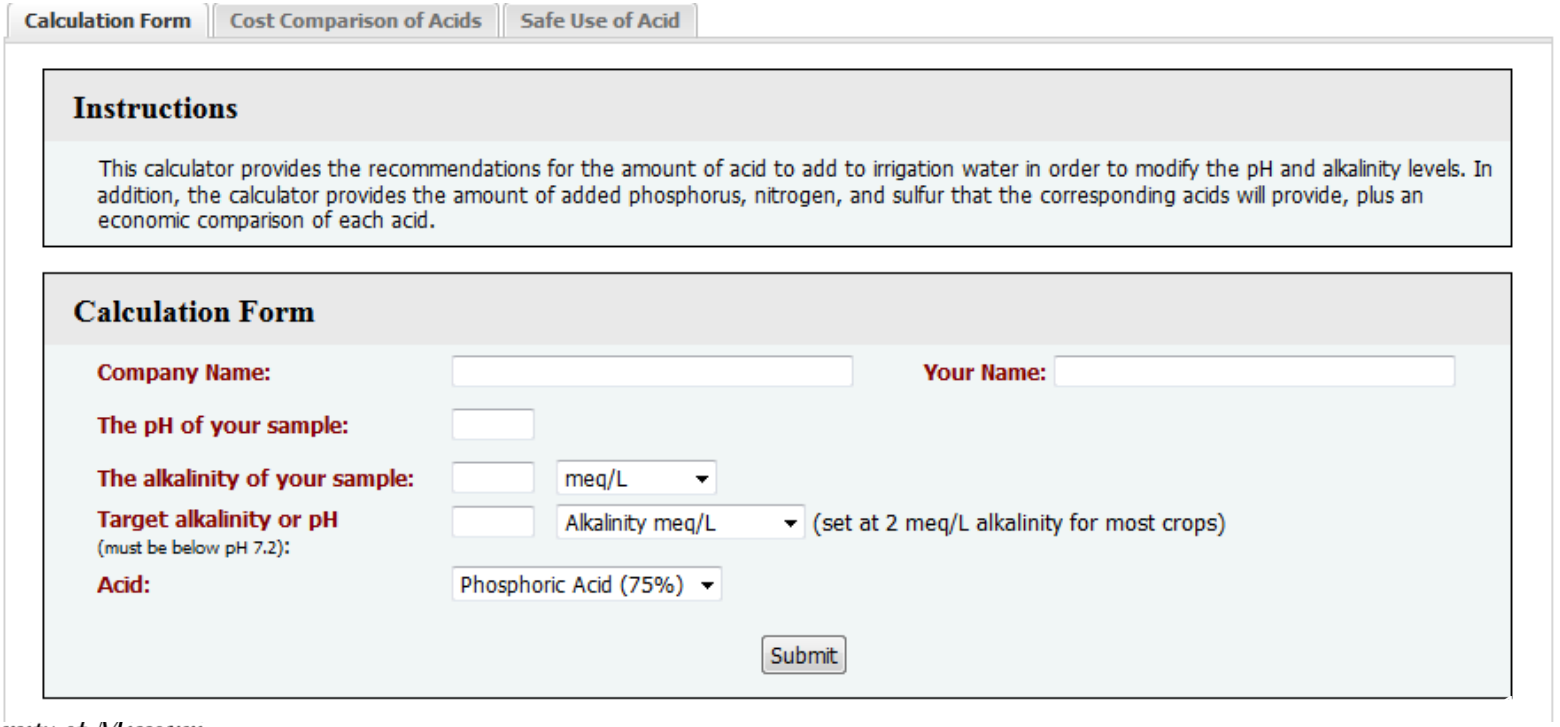


How much acid you need?

- Online calculator:

e-Gro Alkalinity Calculator

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



Water quality for aquaponics

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

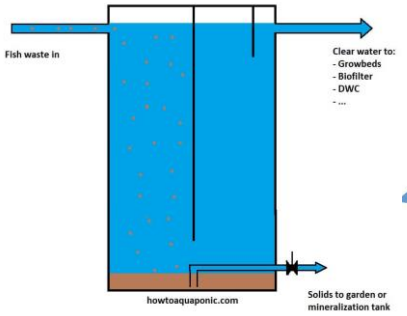
Parameter	Catfish	Biofilter	Lettuce	Tomato	General system
Temperature (°F)	75 - 86	> 68	75	77	75 - 86
Dissolved oxygen (ppm)	5 - 15	> 4	> 6	> 6	6
pH	6 - 8	7 - 9	5.5 - 6.5	5.5 - 6.5	6.8 - 7
Ammonia (NH3, ppm)	< 1	-	< 1	< 1	< 1
Nitrite ($NO2^-$)	0 - 1	-	0 - 1	0 - 1	0 - 1
Nitrate ($NO3^-$, ppm)	< 150	-	125 - 150	125 - 225	150

Solid separators

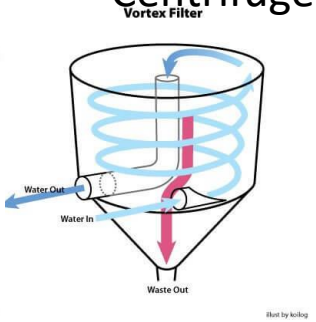
- Non-decomposed material clogs the system and its degradation lowers the dissolved oxygen.
- Bacteria in the biofilter, fishes, and plants NEED oxygen

GRAVITY

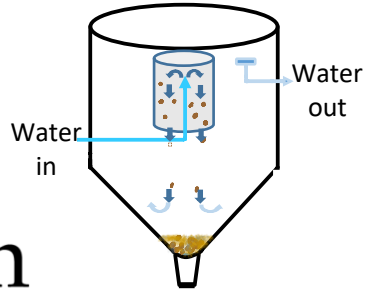
Clarifier



Centrifuge

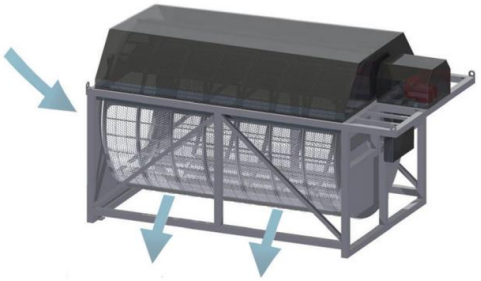


Radial flow



FILTRATION

Screen filter



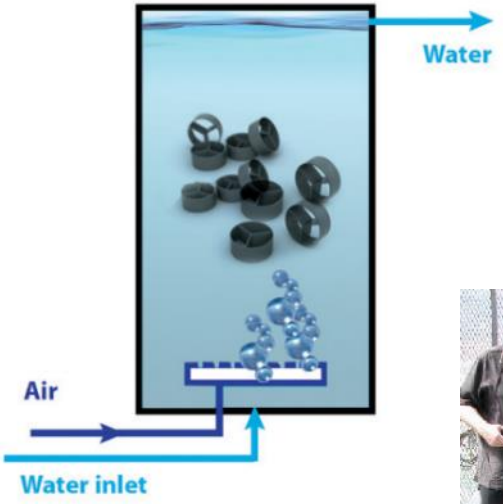
Granular media

Biofilter

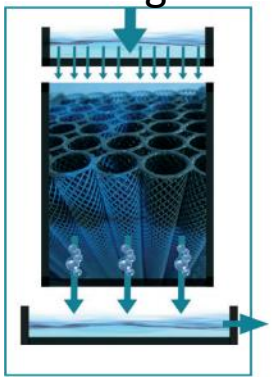
- Bacteria in the **biofilm** transform toxic forms of nitrogen to nitrate (safe for fish and plants)

Granular media

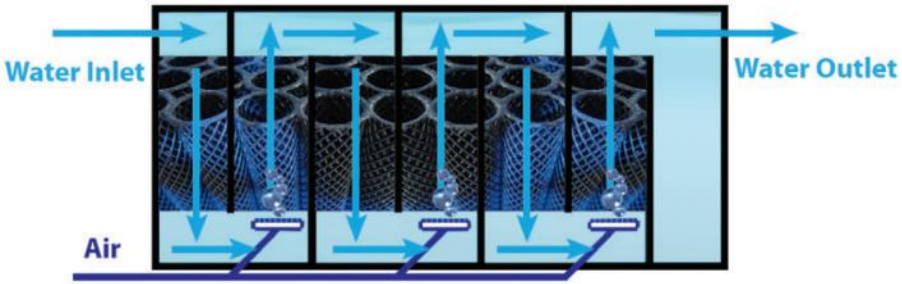
Moving bed biofilter



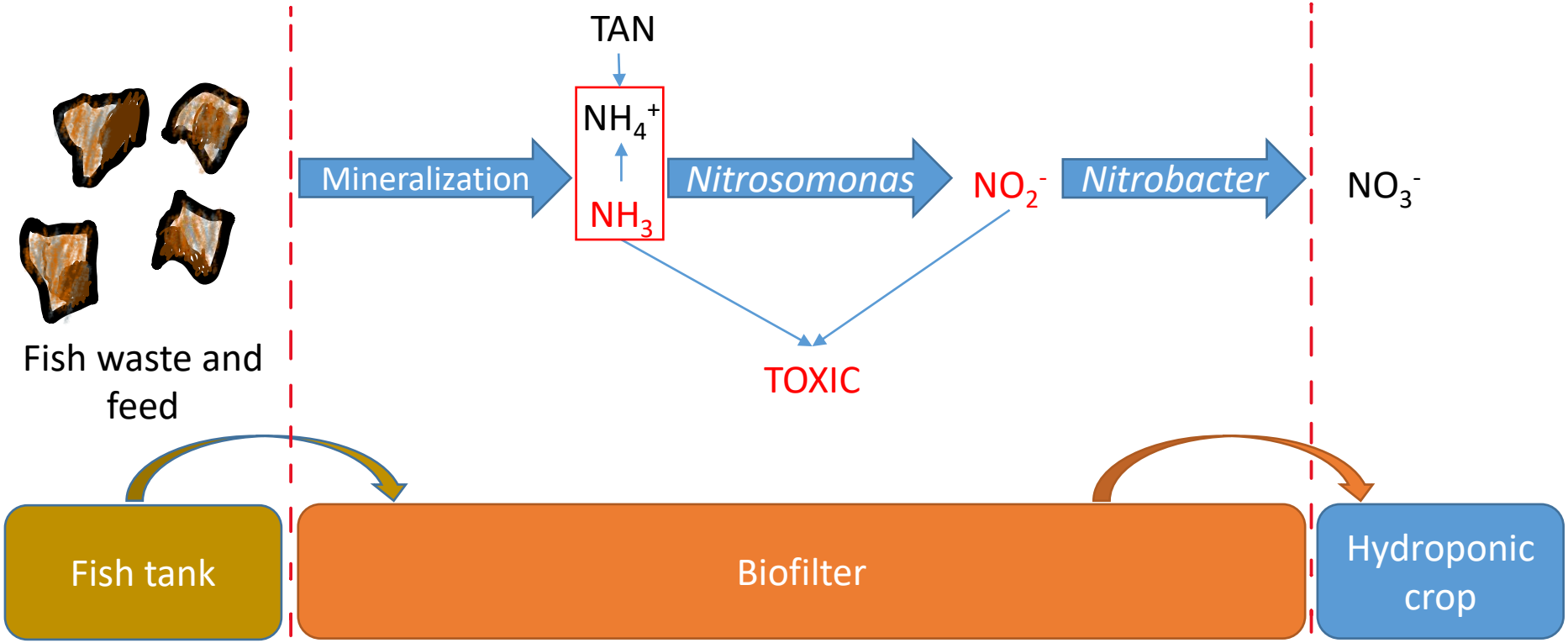
Trickling filter



Fixed bed biofilter



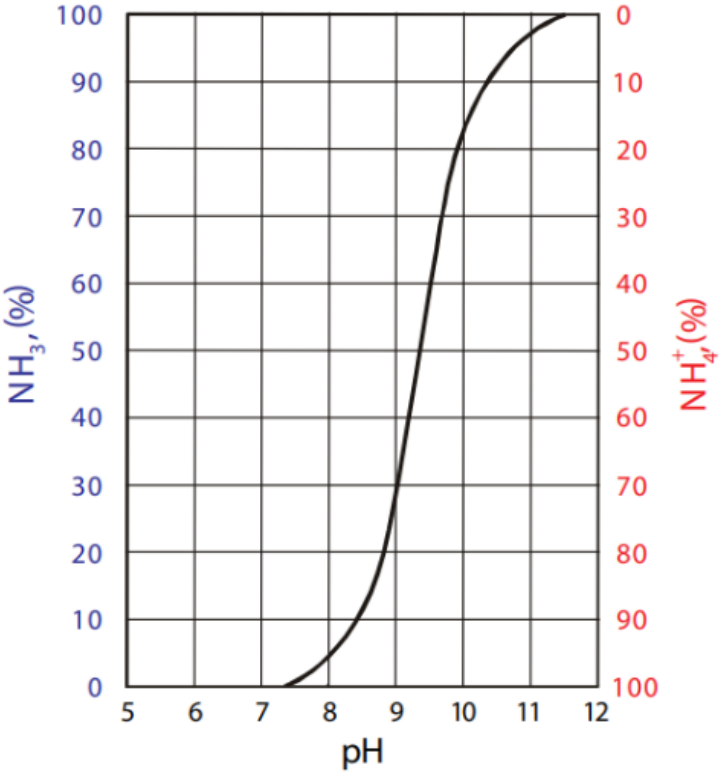
Nitrogen cycle in aquaponics



Nitrogen management determines the success of an aquaponic system!

Total ammoniacal nitrogen (TAN)

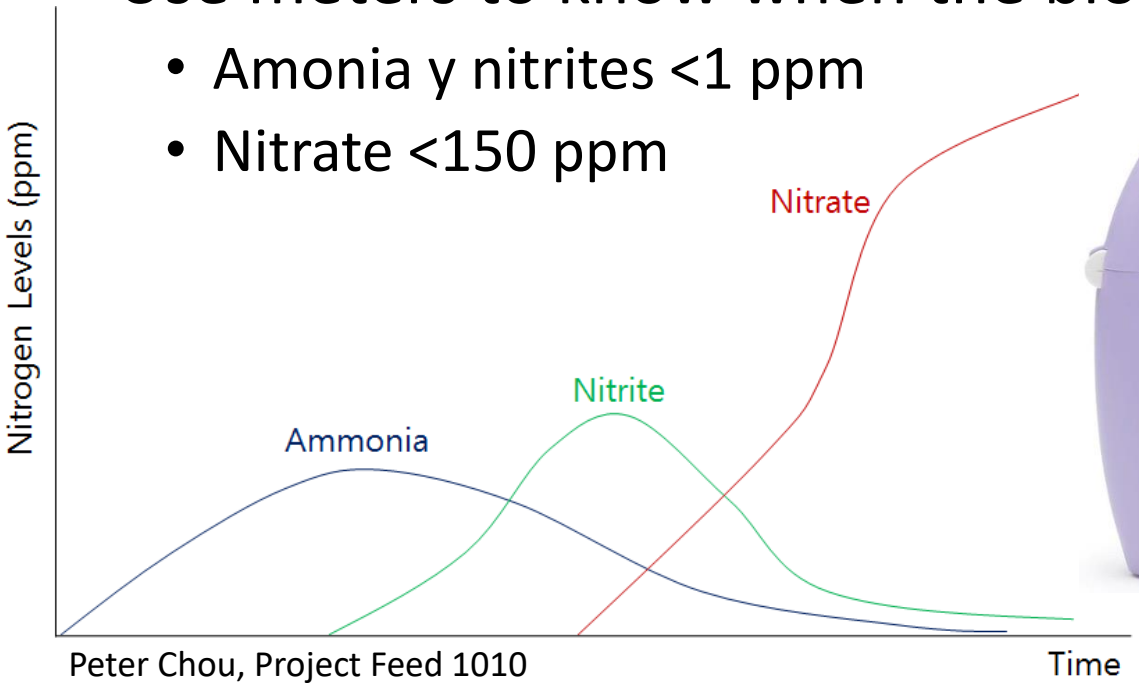
- Includes toxic (NH3) and nontoxic (NH4+) forms.
- The nontoxic form prevails with pH under 7 and temperatures under 87°F/31°C



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
  - Amonia y 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/día
  - 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

Common Problems

Dispersion of plant Pathogens

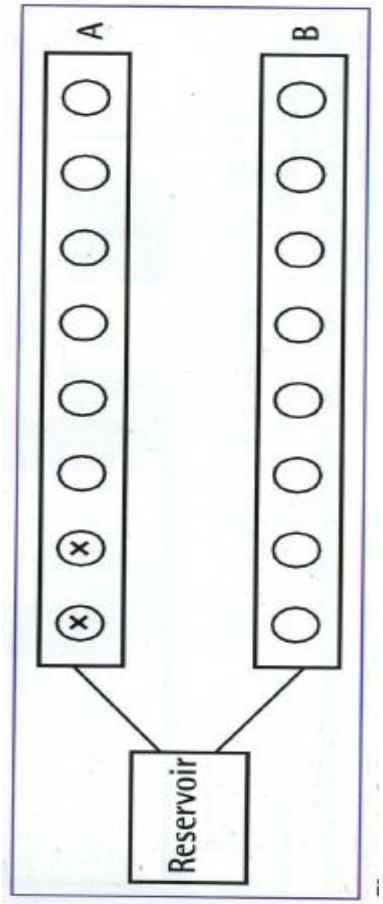


Fig. 4. Mortality of pepper plants on the inoculated and noninoculated side of a two-sided ebb-and-flow cultural system in the **(A)** absence or **(B)** presence of a surfactant in the recirculating nutrient solution. X = the inoculated plants that served as the source of secondary inoculum.

Common Pathogens in Hydroponics

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

Temperature and Diseases

20-30% of losses occur in the summer

Temperature

- Lettuce: root 75°F; air→Day 68°F-75°F→Night 60°F-65°F
  - Tomatoes 77°F
  - Spinach: root 72°F; air 61°F - 91°F

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

Accumulation of algae

Algae in indoor production

Algaes

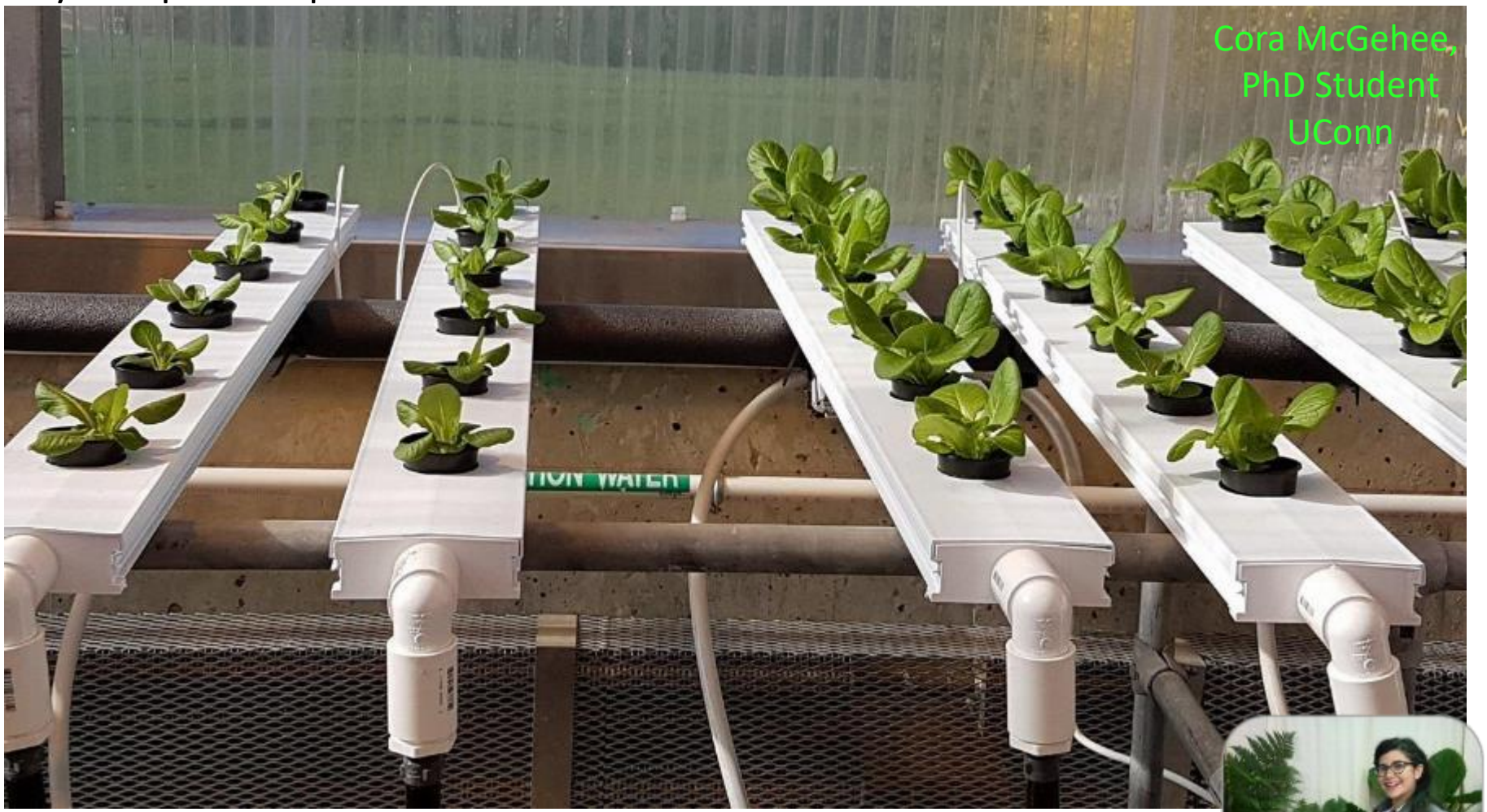
Factors that affect the growth of algae:

- Nutrients
- Water
- Light

Disinfection: Reduce inoculum

Disinfection: Reduce inoculum

Biocontrol in organic production still not compatible with hydroponic production



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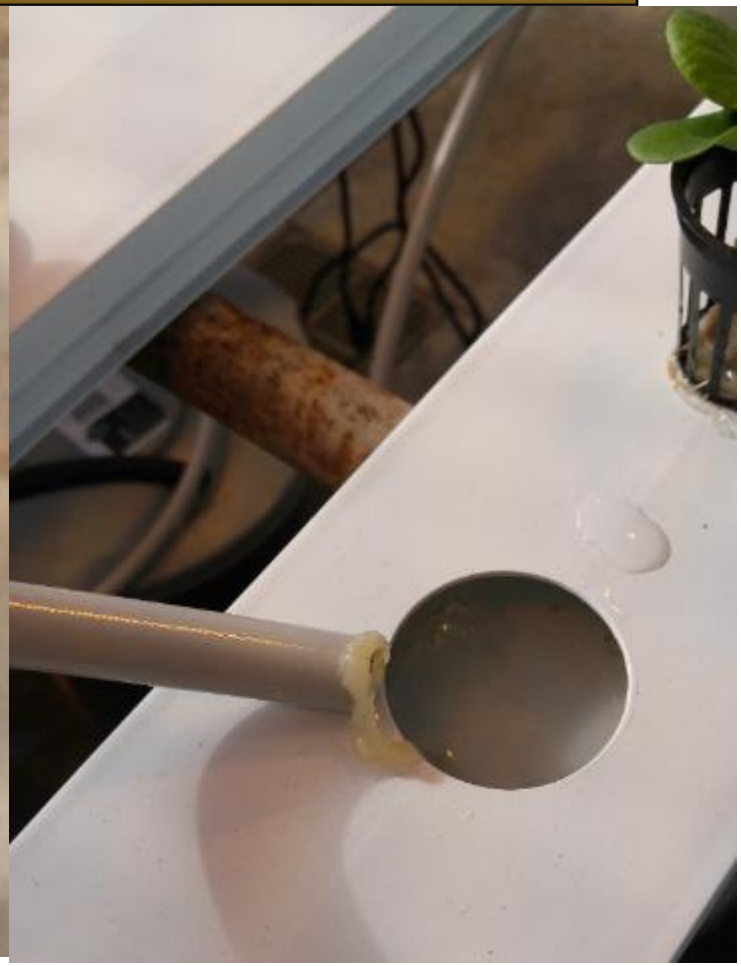
Production organic: Obstruction



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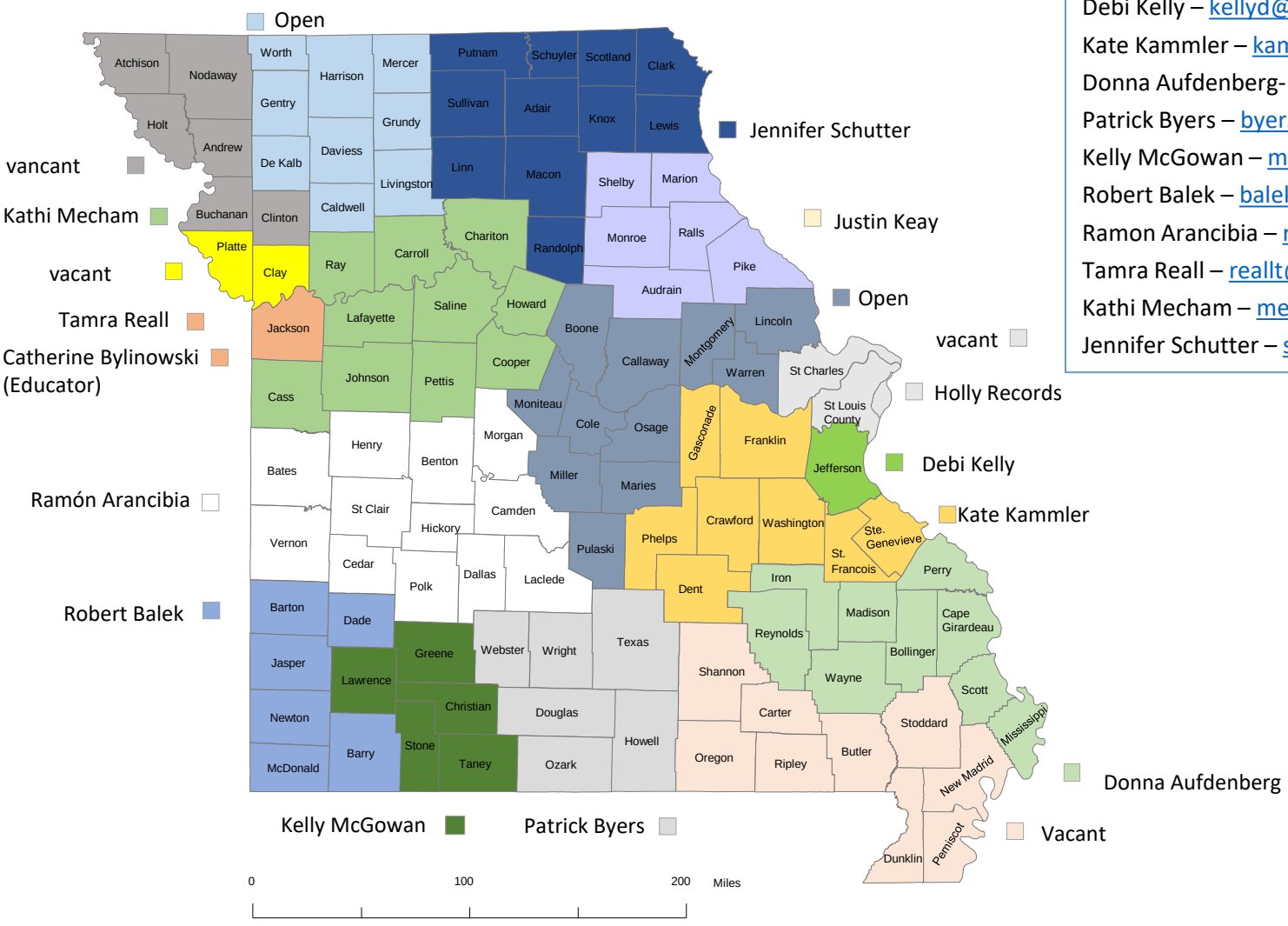

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