Fertilizer and water quality management for hydroponic crops

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It begins with water…

What is your irrigation water source?

pH?

alkalinity? (HCO_3^-, CO_3^{2-} liquid limestone)

EC (electrical conductivity)?

Specific elements (Ca, Mg, Na, Cl)

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What is your irrigation water source?

~~pH?~~

alkalinity? (liquid limestone)

EC (electrical conductivity)?

Specific elements (Ca, Mg, Na, Cl)

General Water Quality Guidelines

Recommended upper limits for water source

pH	5.4-7.0 acceptable
Alkalinity	100 ppm $CaCO_3$
EC	< 1 dS/m
Sodium	< 70 ppm
Chloride	< 70 ppm
Sulfates	< 90 ppm
Boron	< 0.5 ppm
Fluoride	< 1.0 ppm
Iron	< 5.0 ppm

Adapated from: Bailey et al., 1999

Factors that effect root-zone pH:

- the alkalinity of the tap water - carbonates/bicarbonates which will increase the pH of the container media over time
- fertilizers that are used
  - ammonium or urea based fertilized tend to acidify the root media
  - nitrate based fertilized tend to increase the root media pH
- Use of acids to decrease pH

Alkalinity

Alkalinity – the ability of water to neutralize acids

- due to the presence of dissolved alkalis: $Ca(HCO_3)_2$, $NaHCO_3$, $Mg(HCO_3)_2$, $CaCO_3$
- Do not confuse with “Alkaline” which means pH level greater than 7
- Reported in terms of ppm $CaCO_3$ (or meq; 50 ppm = 1 meq $CaCO_3$)
- Typically varies from 50-500 ppm

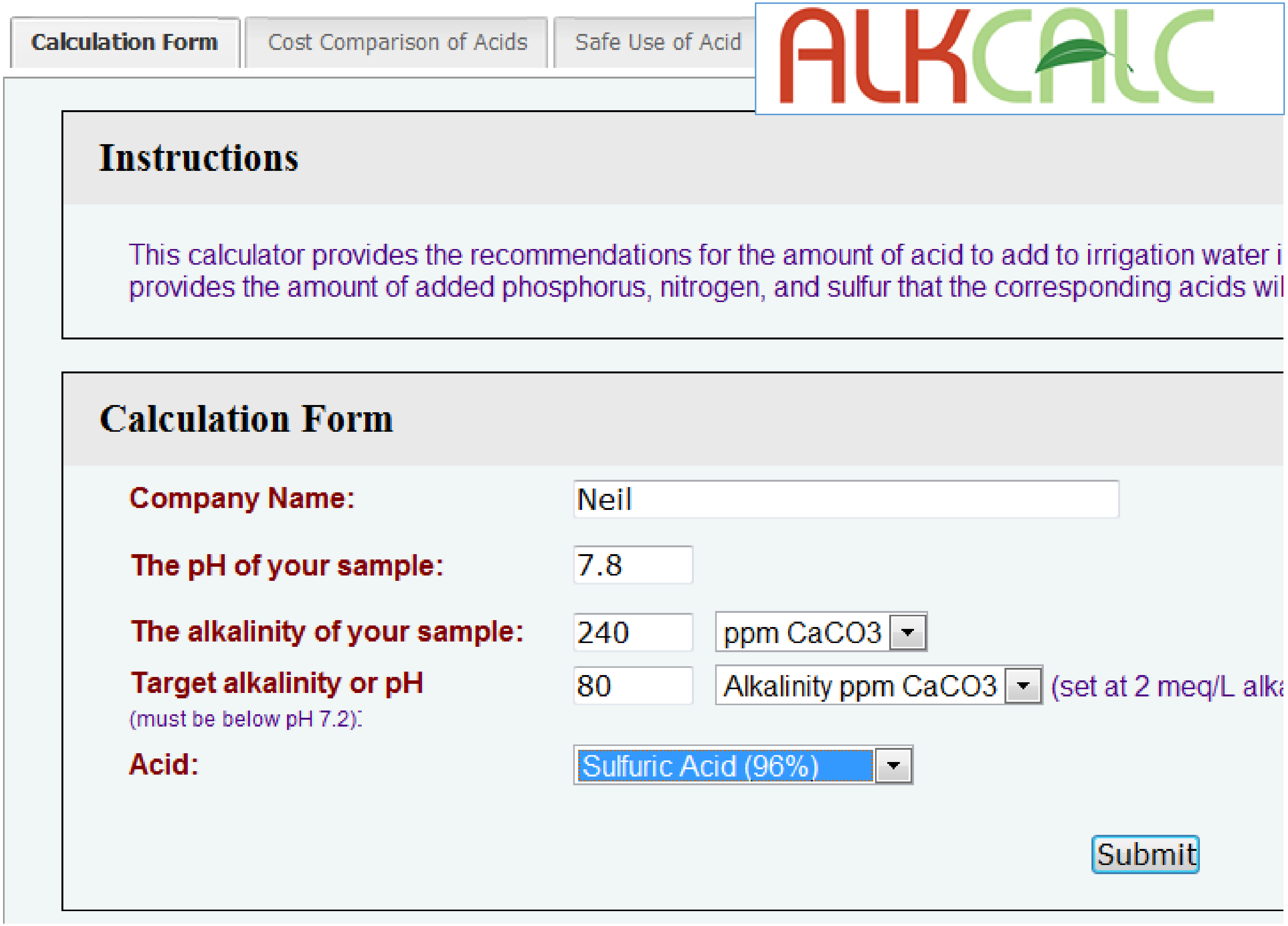
Correcting High Alkalinity

1) Change or blend the water source
   - Ex: rainwater (very low alkalinity) with moderate alkalinity well water
2) Use an acidic fertilizer
   - Fertilizers with ammonium-nitrogen
3) Inject acid into irrigation water

Acid Injection

Acidification reduces the amount of carbonates and bicarbonates

H^+ (from acid) + HCO_3^- (in water) → $CO_2 + H_2O$



http://extension.unh.edu/Agric/AGGHFL/growing_tools.htm

ALKCALC

Amounts	Sulfuric Acid (96%)
For Small Volumes	
ml per liter	0.089
fl. oz. per gallon	0.011
ml per gallon	0.338
For a 1:100 Injector	
fl. oz. per gallon (conc.)	1.14
ml per gallon (conc)	33.77
For a 1:128 Injector	
fl. oz. per gallon (conc.)	1.46
ml per gallon (conc)	43.22
For a 1:200 Injector	
fl. oz. per gallon (conc.)	2.28
ml per gallon (conc)	67.53

Which Acid to Use?

- Safety
  - Nitric acid is very caustic and has harmful fumes
  - Sulfuric, Phosphoric, Citric relatively safe
- Cost
  - Sulfuric is cheapest, others are 2-4 times more expensive
- Nutrients from Acid
  - Sulfuric provides S
  - Nitric provides N
  - Phosphoric provides P (but can be too much if equilibrating >100 ppm alkalinity

Correcting poor quality water

No silver bullet

- Change source
  - Municipal? Well?
- pondwater
- rainwater
- RO water
- Ion exchange

(Or some combination of blending the above with your current water source)

More on RO and Ion Exchange Demineralization

Case Study: hydroponic lettuce greenhouse – after several years felt that poor quality municipal water → 20% reduction yield

- Reverse Osmosis (RO) system would have cost several thousand dollars and had lots of waste water
- They could not properly dispose of the waste water

Ion Exchange Demineralization

- Two canisters – one traps positively charged molecules, the other negatively charged
- Example from Culligan
- $25 per month take rental
- $125 per recharge
  - with the fairly poor water of this grower – recharge every 4500 gallons
- Compared to RO no real upfront cost, less space
  - perhaps a good choice for smaller/seasonal growers

Case Study – Water Softener
Binghamton University

	Unsoftened	Softened
pH	7.6	7.5
EC (mhos/cm)	0.5	0.5
Ca (ppm)	80	**12**
Mg (ppm)	15	**3**
Na (ppm)	25	**130**
Cl (ppm)	65	65
Alkalinity (ppm)	200	200

Concerns

- Alkalinity is still a problem!
  - Consider injecting acid to neutralize alkalinity
- High sodium is now a problem
  - Regular leaching required
- Now low calcium and magnesium may be a problem
  - Switch to a calcium and magnesium containing fertilizer (ex: 15-5-15 Cal Mag)

The necessary water quality depends on

- the crop grown
- how closely the fertilizer used matches crop needs
  - if does not match closely → nutrient imbalances, some nutrients can build up to toxic levels
- whether the water is captured and reused and how long it is reused for

Open vs. Closed Irrigation

Open system: any excess water leaches to floor/ground

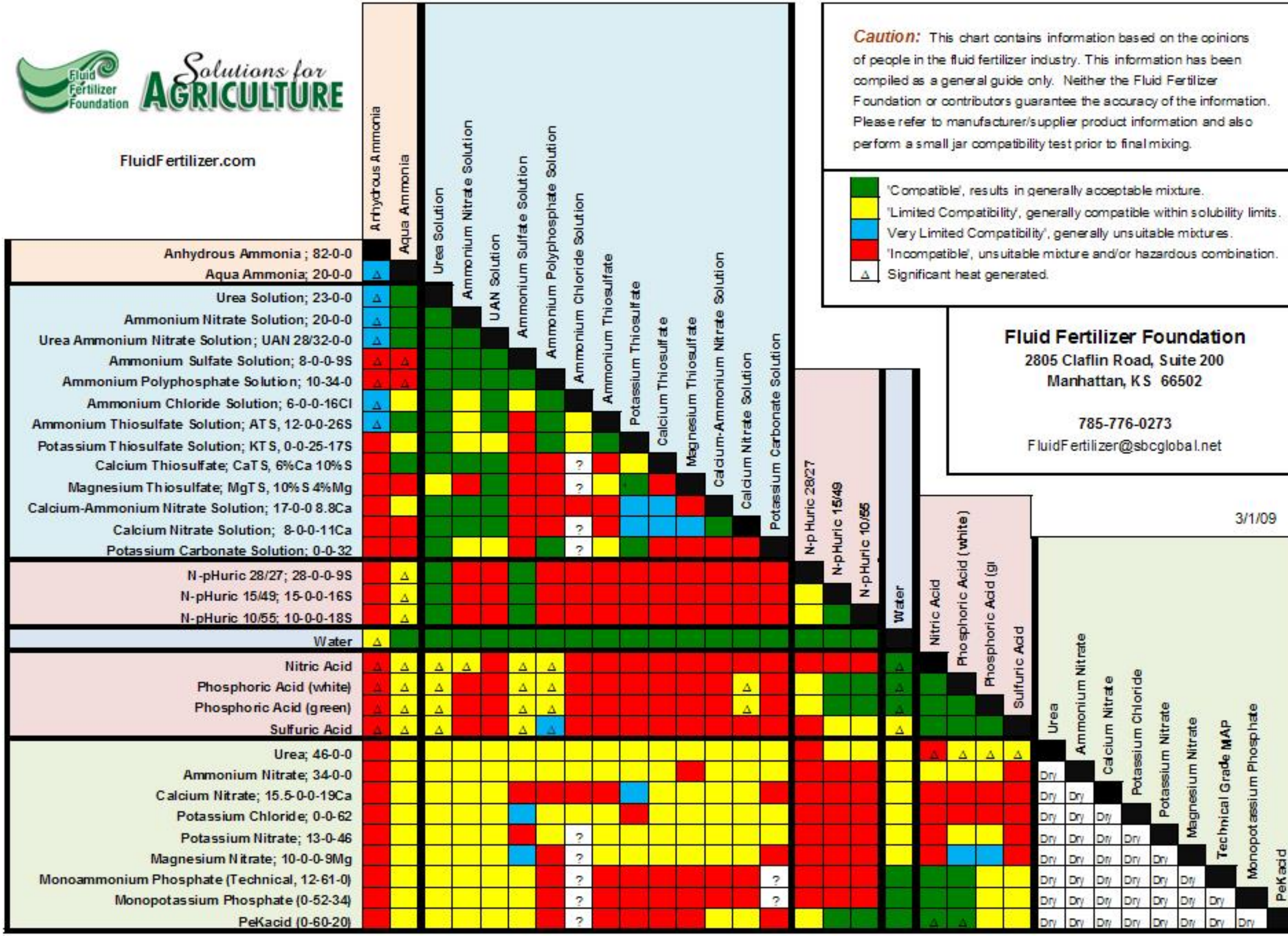
- If excess water applied this can control the build up of salts
- Can use poorer quality water

- Closed system: excess water captured and reused
  - disinfestation to control pathogen spread
  - nutrient imbalances and salt build up over time
  - saves water and fertilizer
  - start with better quality water

Some fertilizers don't play nicely with each other

- Incompatibility – blending of fertilizers results in a precipitate
- Don't mix calcium with phosphate or sulfates

FluidFertilizer.com



Caution: This chart contains information based on the opinions of people in the fluid fertilizer industry. This information has been compiled as a general guide only. Neither the Fluid Fertilizer Foundation or contributors guarantee the accuracy of the information. Please refer to manufacturer/supplier product information and also perform a small jar compatibility test prior to final mixing.

- 'Compatible', results in generally acceptable mixture.
- 'Limited Compatibility', generally compatible within solubility limits.
- 'Very Limited Compatibility', generally unsuitable mixtures.
- 'Incompatible', unsuitable mixture and/or hazardous combination.
- Δ Significant heat generated.

Fluid Fertilizer Foundation
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3/1/09


SUPERDOS 30
A
B

3 Tank System – accounts for precipitation problem

Tank A

- Calcium nitrate
- ½ potassium nitrate
- Iron chelate
- (Nitric acid)

Tank C

- Acid, used to drive down pH (or base if very pure waters, acidic N source)
  - Or Sulfuric/Phosphoric in tank B (NOT with calcium)
  - Nitric in Tank A (with calcium)

Tank B

- ½ potassium nitrate
- Potassium sulfate
- Monopotassium phosphate
- Magnesium sulfate
- All other micronutrients
- Monoammonium phosphate
- Ammonium nitrate
- (sulfuric acid)
- (phosphoric acid)

Use greenhouse grade fertilizers

- Not standard grade
- Higher purity/solubility
- Example greasy coating of calcium nitrate

Fertilizer Article

A Recipe for Hydroponic Success

Neil Mattson and Cari Peters

http://www.greenhouse.cornell.edu/crops/
factsheets/hydroponic-recipes.pdf

Table 3. Target nitrogen feed rates (in ppm N) for several hydroponic crops.

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

* Adapted from data collected at J.R.Peters Laboratory and Smithers Oasis Inc. 2012-2013

Fertilizer Recipes for Leafy Greens and Herbs

- Simple, 1-3 bags
  - Base feed macros/micros
  - Calcium nitrate
  - Magnesium sulfate
- Complex, 11 ingredients

1 bag
Jack's Hydro-Herb FeED 16-4-17

- 355 g in 100 gallons water (dilute)
  - or for each 1 gallon in a stock tank (using a 1:100 injector)

F1313

GUARANTEED ANALYSIS

Total Nitrogen (N) 16%
3.5% Ammoniacal Nitrogen
12.5% Nitrate Nitrogen
Available Phosphate (P_2O_5) 4%
Soluble Potash (K_2O) 17%
Calcium (Ca) 4%
Magnesium (Mg) 2%
2% Water Soluble Magnesium (Mg)
Boron (B).................. 0.016%

Copper (Cu)............. 0.009%
0.009% Chelated Copper (Cu)
Iron (Fe) 0.1%
0.1% Chelated Iron (Fe)
Manganese (Mn)........ 0.05%
0.05% Chelated Manganese (Mn)
Molybdenum (Mo)... 0.008%
Zinc (Zn)..................... 0.04%
0.04% Chelated Zinc (Zn)

2 bag
Jack's Hydroponic (5-12-26)
+ Calcium nitrate

Tank A	Tank B
284 g $Ca(NO_3)_2 \cdot 3H_2O$	284 g 5-12-26

Grams per 100 gallons dilute, or for each 1 gallon in a stock tank (using a 1:100 injector)

HORT AMERICAS
HYDROPONIC FERTILIZER

9-7-37

Hort Americas is an innovative leader in North America's controlled environment agriculture industry (CEA). Hort Americas strives to innovate agriculture via premium technical support, professional salesmanship, unmatched customer service and outstanding products to our customers in the United States, Canada, Mexico and the Caribbean. In our efforts to fuel progress in CEA we are proud to release Hort Americas Hydroponic Fertilizer.

Hort Americas has developed this unique fertilizer in cooperation with CEA hydroponic specialists, academicians and researchers to meet the nutritional needs of crops produced by hydroponic leafy green growers.

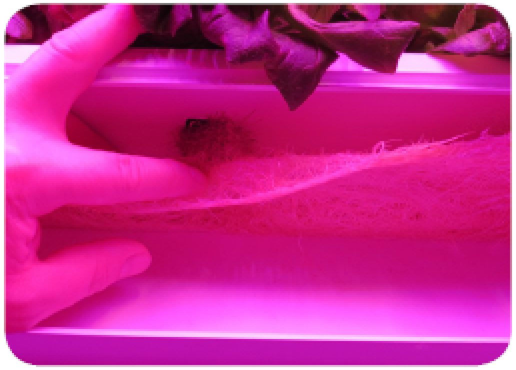
DIRECTIONS FOR USE

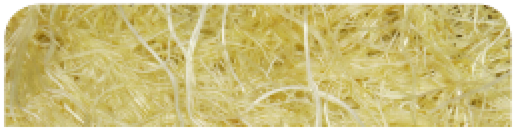
These are general guidelines that need to be adjusted to your hydroponic system, environmental conditions, and to the quality of your source water.

HYDROPONICS: Have your source water tested by a professional water analysis laboratory to determine its nutrients, pH, EC and total alkalinity. Calcium nitrate, potassium nitrate, magnesium sulfate, chelated iron, or any other plant essential elements can be added as determined by plant response, tissue analysis, or nutrient solution analysis.

SUGGESTED RATES:

0.271 to 0.455 lbs/100 gallons - 1.23 to 2.06 grams/1 gallon (3.785 L)
Add to the nutrient solution 3.58 grams/gallon of calcium nitrate and 1.67





3 bag
Hort Americas Hydroponic 9-7-37
+ Calcium nitrate
+ Magnesium sulfate

Tank A	**Tank B**
280 g $Ca(NO_3)_2 \cdot 3H_2O$	150 g 9-7-37 160 g $MgSO_4 \cdot 7H_20$

Grams per 100 gallons dilute, or for each 1 gallon in a stock tank (using a 1:100 injector)

Sonneveld's Solution (Lettuce Recipe)

Tank A	**Tank B**
184.0 g $Ca(NO_3)_2 \cdot 3H_2O$	51.5 g KH_2PO_4
14.4 g NH_4NO_3	93.1 g $MgSO_4 \cdot 7H_20$
167.3 g KNO_3	*0.290 g $MnSO_4 \cdot H_2O$
*3.8 g 10% Iron-DTPA	*0.352 g H_3BO_3
Sprint 330 or	*0.023 g $Na_2MoO_4 \cdot 2H_2O$
Sequestrene 330	*0.217 g $ZnSO_4 \cdot 7H_2O$
	*0.035g $CuSO_4 \cdot 5H_2O$

Grams per 100 gallons dilute, or for each 1 gallon in a stock tank (using a 1:100 injector)

How do they stack up?

	16-4-17	5-12-26 + Cal. Nit.	9-7-37 + Cal. Nit. + Mag. Sulf.	Sonneveld's solution
Nitrogen	**150**	**150**	**150**	**150**
Phosphorus	16	39	12	31
Potassium	132	162	122	210
Calcium	38	139	133	90
Magnesium	14	47	42	24
Iron	2.1	2.3	2.0	1.0
Manganese	0.47	0.38	0.75	0.25
Zinc	0.49	0.11	0.75	0.13
Boron	0.21	0.38	0.36	0.16
Copper	0.131	0.113	0.20	0.023
Molybdenum	0.075	0.075	0.04	0.024

Tomato, pepper, cucumber

Table 4. Two hydroponic nutrient solution recipes to prepare 100 gal. of fertilizer suitable for hydroponic production of tomatoes, cucumbers and peppers.

Jack's Hydroponic (5-12-26) + Calcium nitrate	
Tank A	**Tank B**
360 g Calcium nitrate (15-0-0)	360 g 5-12-26

UA CEAC Recipe*	
Tank A	**Tank B**
347.8 g $Ca(NO_3)_2 \cdot 3H_2O$	64.9 g KH_2PO_4
152.5 g KNO_3	184.3 g $MgSO_4 \cdot 7H_20$
*7.6 g 10% Iron-DTPA Sprint 330 or Sequestrene 330	114.7 g K_2SO_4
	*0.641g $MnSO_4 \cdot H_2O$
	*0.606g H_3BO_3
	*0.048g $Na_2MoO_4 \cdot 2H_2O$
	*0.549g $ZnSO_4 \cdot 7H_2O$
	*0.074g $CuSO_4 \cdot 5H_2O$

*A precise scale is needed to weigh the micronutrients

Adapted from University of Arizona, Controlled Environment Agriculture Center, http://tinyurl.com/ljlj785/

	Jack's Hydroponic (5-12-26) + Calcium nitrate	UA CEAC Recipe
Nitrogen (N)	190	189
Phosphorus (P)	50	39
Potassium (K)	205	341
Calcium (Ca)	176	170
Magnesium (Mg)	60	48
Iron (Fe)	2.85	2.00
Manganese (Mn)	0.48	0.55
Zinc (Zn)	0.14	0.33
Boron (B)	0.48	0.28
Copper (Cu)	0.14	0.05
Molydenum (Mo)	0.10	0.05

Can adjust fertilizer with crop stage

3 stages

- UA CEAC A: Tomato, Stage 1 (seedling to 2nd truss anthesis)
- UA CEAC B: Tomato, Stage 2 (2nd to 5th truss anthesis)
- UA CEAC C: Tomato, Stage 3 (after 5th truss anthesis); or so-called ‘multi-crop recipe’

- Low N → Higher N (encourage generative growth initially)
- Increasing K/Ca (needed in greater quantities during fruiting)

Element	UA-CEAC A (Tomato at Stage 1)	UA-CEAC B (Tomato at Stage 2)	UA-CEAC C (Tomato at Stage 3; or Multi-crop)
NO_3-N	**90**	**120**	**190**
NH_4-N	0	0	0
P	47	47	47
K	**144**	**350**	**350**
Ca	**144**	**160**	**200**
Mg	60	60	60
S	116	116	116
Cl	89	89	89
Fe (EDTA)	2	2	2
Mn	0.55	0.55	0.55
Zn	0.33	0.33	0.33
Cu	0.05	0.05	0.05
B	0.34	0.34	0.34
Mo	0.05	0.05	0.05

What to do if have only 1 injector?

- Prepare the two stock tanks
- But use only 1 at a time
  - Alternate days (ideal) or half of week
- Concentration of fertilizer should be doubled
  - As plants receive each only ½ of the time

Soilles/Hydroponic growing requires vigilance!

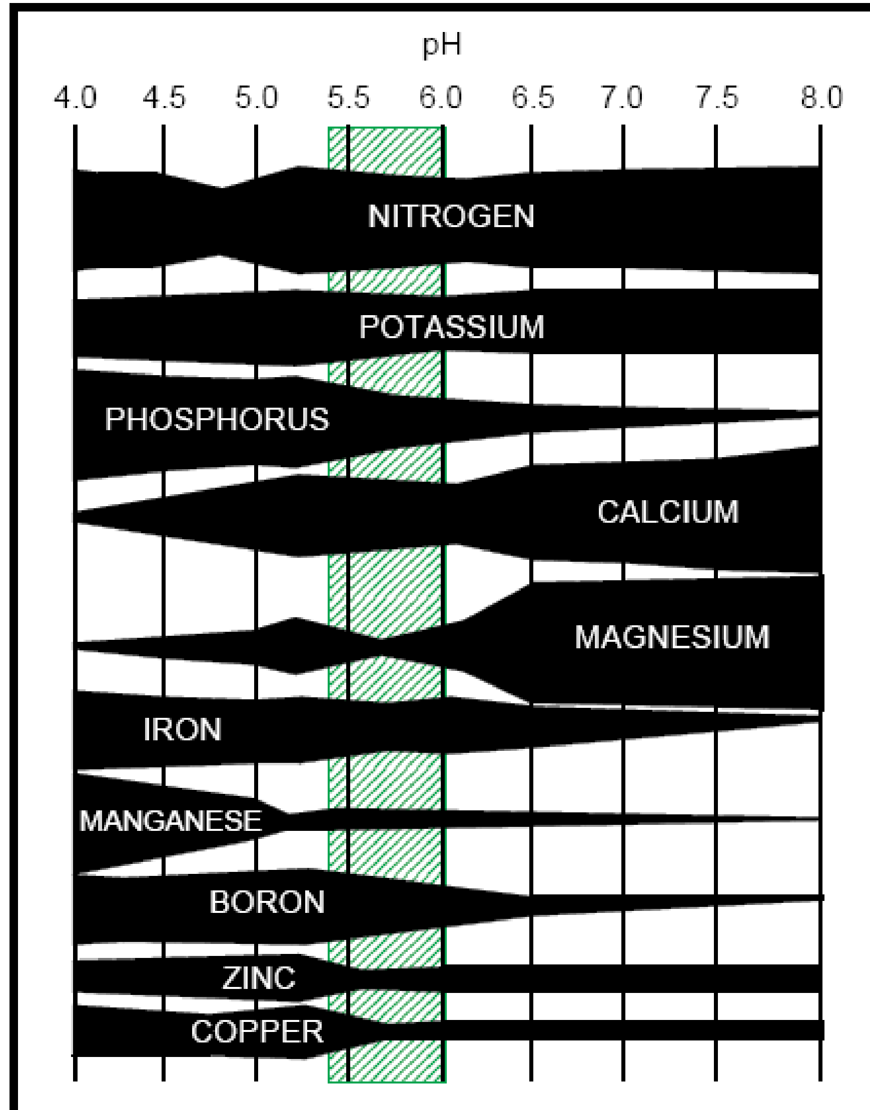
pH and Electrical conductivity (EC) testing

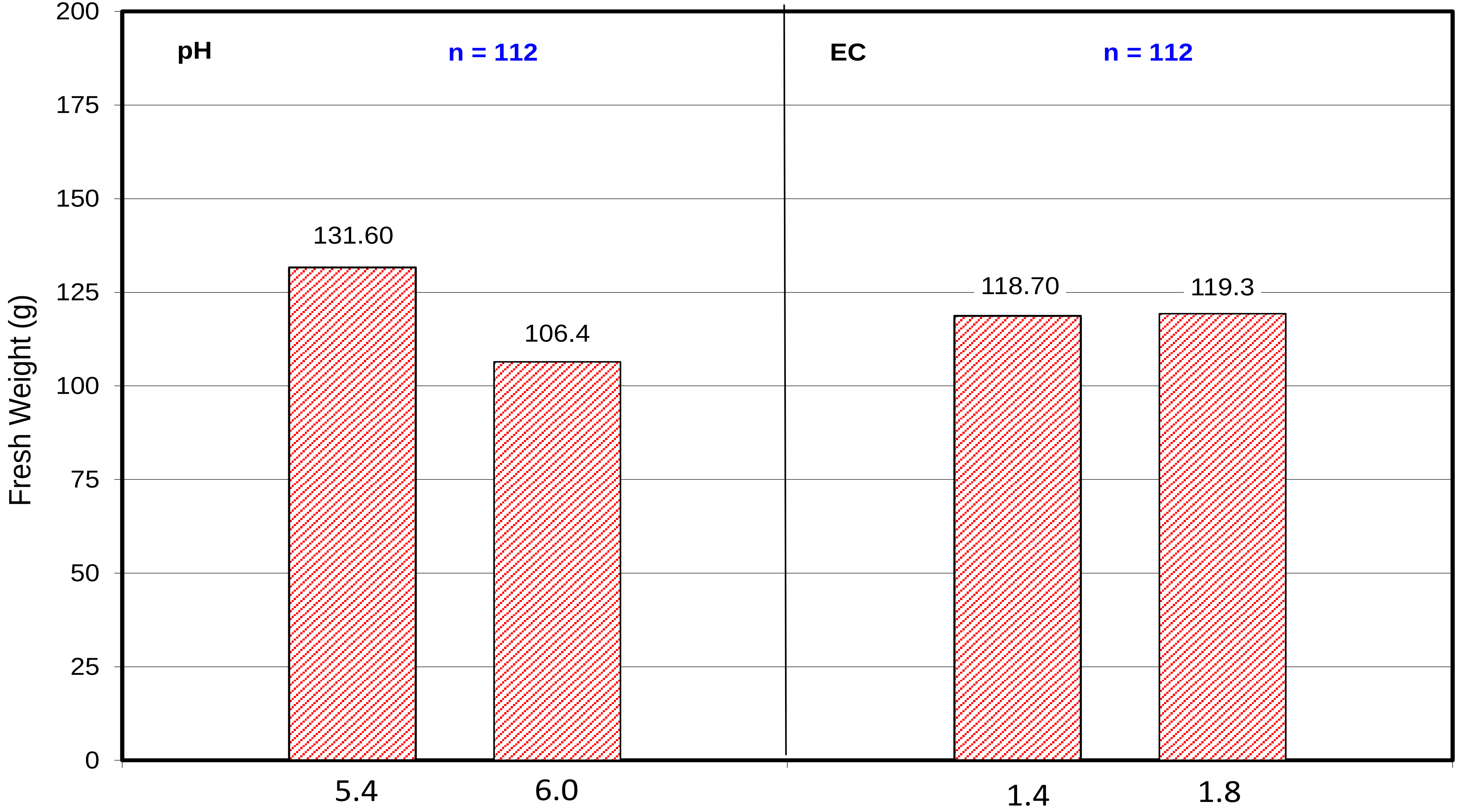
- Test early, test often
- How often to test depends on your system
    - In hydroponics: every day
    - In bag culture: perhaps 1-2 times per week

pH/EC – what is optimal

- pH: effects plant nutrient availability →
    - optimal: 5.5 – 6.5
    - in hydroponics a bit lower is better: 5.4-6.0

- EC depends on crop
    - in general 1-2 dS/m (=1-2 mhos/cm) from the fertilizer
    - avoid salt build up in the root zone > 4.0





pH and EC effect on hydroponic lettuce

pH 5.4 → 24% higher yield, Robert Hansen, 2008

Fertilizer (EC) and pH control

- Manual – check and adjust by hand
  - Ex: Pond (pH adjusted daily), fertilizer tested every two weeks and adjusted
- Automated, pH and EC sensors control pumps with dilute acid/base, and fertilizer stock
  - Sensors drift, important to check and calibrate!

Automated Control examples

Adjust reservoir/pond

Hanna HI 2500

- 3 peristaltic pumps
  - 1 dilute acid
  - 2 fertilizer stocks

Adjust fertilizer water

Hanna HI 10,000

- 5 injectors
  - 1 for dilute acid
- 5-300 gpm flow rate

Common nutritional disorders and corrections

Nitrogen Deficiency – yellow lower leaves, reduced biomass

Iron Deficiency

Magnesium Deficiency – interveinal chlorosis of **LOWER** leaves

http://www.e-gro.org/ Research Update Symptoms Lettuce Nutrient Deficiencies

e-GRO Research Update
October 2015, #2015.09

Cornell University

Symptoms of Common Nutrient Deficiencies in Hydroponic Lettuce

by Neil Mattson and Tanya Merrill

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Managing the nutrient solution of hydroponic crops can be much more challenging than container grown crops because: 1) hydroponic solutions are often captured and reused which can, overtime, lead to deficiencies of some elements and excess of others; and 2) pH changes much more quickly in hydroponics than in container-grown plants. Hydroponic growers should monitor nutrient solution pH and EC daily as well as periodically have their nutrient solution tested by a laboratory to make sure nutrient supply meets plant needs. Monitoring plants to look for visual symptoms is another tool that can be used to detect nutrient deficiencies. Lettuce is one of the most commonly grown hydroponic vegetables. Currently there are few resources in the literature regarding photographs and descriptions of common nutrient disorders in hydroponic lettuce. Therefore, the objective of this study was to grow butterhead

Summary of Findings

Physiological disorders related to water management

- Blossom End Rot
  - A Ca deficiency, typically caused by poor transpiration
    - Water management (avoid drying out substrate)
    - Transpiration (air flow, relatively humidity)

Physiological disorders related to water management

- Fruit Cracking
  - Excessively fast water absorption into fruit
  - Water deficit followed by sudden watering
  - Excess fruit temperature

Leaf Tipburn, Calcium Deficiency


Leaf tip burn
Avoid excessive light > 17 mol DLI
And maintain good airflow

Lettuce and Light

- 17 mol m^{-2} d^{-1} target
  - Assumes good air flow (paddle fans)
- If > 17 mol m^{-2} d^{-1} for 3 days in a row → leaf tip burn
- If poor air flower or concerned about tip burn, set a lower target 12-14 mol m^{-2} d^{-1}
- Days to harvest at:
  - 17 mol 35 days
  - 10 mol 60 days
  - 5 mol 119 days!

Tissue Testing

- For the most common vegetables commercial testing labs have detailed:
  - tissue collection procedures
  - dates of collection tied to crop stage
  - and standard ranges for comparison

Tomato what leaves to test

- (The tip leaf of the compound leaf)
- Usually from recently mature leaves just below the cluster being set
- Leaves from 12 plants that were dispersed across the greenhouse
- Place in paper bag and send to lab

Tomato – interpreting foliar analysis sufficiency range in % dry weight

Element	Early fruit set	Mid-harvest
N	4.5 – 6.0%	4.5 – 5.5%
P	0.3 – 0.9	0.6 – 0.8
K	4.0 – 7.0	4.0 – 7.0
Ca	1.5 – 3.5	1.5 – 5.0
Mg	0.4 – 0.7	0.4 – 1.5
Fe	60-300 ppm	60-300 ppm

Commercial testing labs

- A&L Eastern Laboratories http://www.aleastern.com/
  - $24-30 ($2 extra for tissue recommendation using NutriScription®)
- JR Peters Laboratory http://www.jrpeters.com/
  - $36 for tissue, media, or water analysis (soil does not include OM)
- Macro Micro Laboratory http://www.mmilabs.com/
  - $45 for tissue, media, soil, or water analysis
- Everris Testing Laboratory http://protestinglab.everris.us.com/
  - $34 for tissue, media, soil or water analysis

QUESTIONS?

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