PURDUE AGRICULTURE | HORTICULTURE & LANDSCAPE ARCHITECTURE

How to Select the Right Fertilizer for Hydroponics

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Developing a Nutrient Program

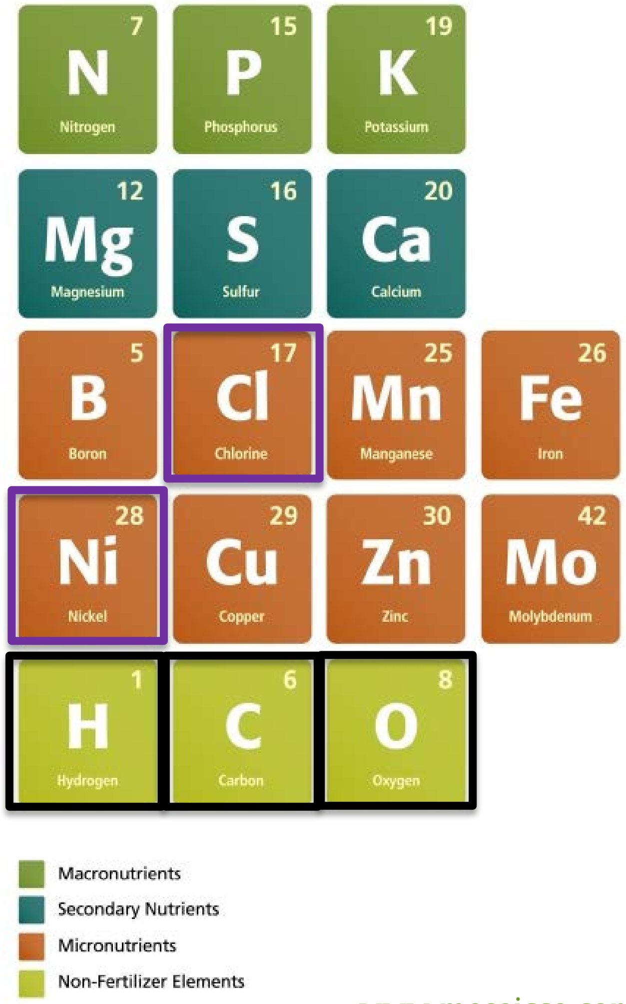
- Laboratory analysis of your water
- Take different nutrient sources into account (substrate, water, fertilizer)
- Different crops may have different needs
- Numerous published nutrient solution formulations exist
- For vegetative crops, most nutrient-solution recipes don't adjust the ratio of nutrients while they grow
- In fruiting crops, the ratio may be adjusted to alter the shift between vegetative and reproductive growth
- Most new growers use one recipe that works well for a range of crop growth stages and conditions

Optimize Nutrient Solution Formulation Based on:

- Crop grown
- Plant growth stage (vegetative, reproductive, etc.)
- Changing environmental conditions (light intensity and duration, temperature, etc.)
- Changing plant stress conditions (increase or decrease EC)
- Changing pH of the rooting medium
- Need to alter nutritional status of plant to counter an insufficiency

14 Essential Elements

Thus, 12 elements applied in a fertilization program



www.mosaicco.com

	Concentration in Dry Tissue		
Element	*Symbol*	*ppm*	*%*
Major Elements			
Carbon	C	450,000	45
Oxygen	O	450,000	45
Hydrogen	H	60,000	6
Nitrogen	N	15,000	1.5
Potassium	K	10,000	1.0
Calcium	Ca	5,000	0.5
Magnesium	Mg	2,000	0.2
Phosphorus	P	2,000	0.2
Sulfur	S	1,000	0.1
Micronutrients			
Chlorine	Cl	100	0.01
Iron	Fe	100	0.01
Manganese	Mn	50	0.005
Boron	B	20	0.002
Zinc	Zn	20	0.002
Copper	Cu	6	0.0006
Molybdenum	Mo	0.1	0.00001

Source: Ames, M. and Johnson, W.S., 1986, in Proceedings of the 7th Annual Conference on Hydroponics: The Evolving Art, The Evolving Science, Hydroponic Society of America, Concord, CA.

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Irrigation Water Quality Guidelines

	Upper Limit	Optimum Range	Comments
pH	7.0	5.5 – 6.5	
EC	1.25 mS·cm^{-1}	<0.25 closed system <1.0 open system	0.75 mS·cm^{-1} for plugs and seedlings. High EC can be the result of accumulation of a specific salt which can reduce crop growth
Total Alkalinity (as $CaCO_3$), acid-neutralizing or buffering capacity	150 mg·L^{-1}	0 – 100 mg·L^{-1}	Measures the combined amount of carbonate, bicarbonate and hydroxide ions. 30 – 60 mg·L^{-1} are considered optimum for plants. pH 5.2, 40 mg·L^{-1} alkalinity; pH 5.8, 80 mg·L^{-1} alkalinity; pH 6.2, 120 mg·L^{-1} alkalinity. $CaCO_3$ at >150 mg·L^{-1} may increase the incidence of dripper clogging
Hardness (amount of dissolved Ca^{2+} and Mg^{2+})	150 mg·L^{-1} >60 mg·L^{-1} Ca >25 mg·L^{-1} Mg	50 – 100 mg·L^{-1}	Indication of the amount of calcium and magnesium in the water. Calcium and magnesium ratio should be 3 – 5 mg·L^{-1} calcium to 1 mg·L^{-1} magnesium. If there is more calcium than this ratio, it can block the ability of the plant to take up magnesium, causing a magnesium deficiency. Conversely, if the ratio is less than 3-5 Ca:1 Mg, the high magnesium proportion can block the uptake of calcium, causing a calcium deficiency. Equipment clogging and foliar staining problems above 150 ppm
Bicarbonate Equivalent (HCO_3^-)	122 mg·L^{-1}	30 – 50 mg·L^{-1}	Help to stabilize pH. Increased pH and can lead to Ca and Mg carbonate precipitation

mg·L^{-1} = ppm

ALKCALC
https://extension.unh.edu/Agric/AGGHFL/alk_calc.cfm

Alkalinity

- **Ability of water to neutralize acids**; it buffers water against changes in pH
- Reported in terms of parts per million (ppm) $CaCO_3$ or milli-equivalent ($meq \cdot L^{-1}$)
- Water alkalinity can **vary between 50-500 ppm** (1-10 $meq \cdot L^{-1}$)
- Alkalinity affects **how much acid is required to change the pH**

$meq \cdot L^{-1}$	ppm $CaCO_3$	ppm HCO_3^-	ppm CO_3^{2-}	ppm Ca^{2+}
1	50	61	30	20
2	100	122	60	40
3	150	183	90	60
4	200	244	120	80
6	300	366	150	120

Element	Molecular Weight
Ca	40
C	12
O	16
H	1

Range $meq \cdot L^{-1}$	Classification
0 to 1.5	Low
1.5 to 4	Marginal
> 4	High

Source: Nelson, P.V. Greenhouse Operation and Management

No action required	Acid, fertilizer and/or less lime	Acid injection	Reverse Osmosis

→ **1.5** → **3** → **8** → **10**

Alkalinity ($meq \cdot L^{-1}$)

Correcting High Alkalinity

Acid	Amount of acid to add for each meq of alkalinity (fl oz/1,000 gals)*	Concentration of nutrient provided by one fl oz. of acid per 1,000 of water
Nitric (76%)	6.6	1.64 ppm
Phosphoric (75%)	8.1	2.88 ppm
Sulfuric (35%)	11.0	1.13 ppm

Greenhouse substrate and management, D.A. Bailey, W.C. Fonteno and P.V. Nelson, NCSU

Irrigation Water Quality Guidelines

	Upper Limit	Optimum Range	Comments
Calcium	120 $mg{\cdot}L^{-1}$	40 – 120 $mg{\cdot}L^{-1}$	
Magnesium	24 $mg{\cdot}L^{-1}$	6 – 24 $mg{\cdot}L^{-1}$	
Iron	5 $mg{\cdot}L^{-1}$	1 – 2 $mg{\cdot}L^{-1}$	>0.3 $mg{\cdot}L^{-1}$, clogging; 1.0 $mg{\cdot}L^{-1}$, foliar spotting and clogging; above 5.0 $mg{\cdot}L^{-1}$, toxic. Could lead to iron precipitates resulting in plugging of irrigation system emitters
Manganese	2 $mg{\cdot}L^{-1}$	0.2 – 0.7 $mg{\cdot}L^{-1}$	>1.5 $mg{\cdot}L^{-1}$ emitter blockage can occur
Boron	0.8 $mg{\cdot}L^{-1}$	0.2 – 0.5 $mg{\cdot}L^{-1}$	
Zink	2 $mg{\cdot}L^{-1}$	0.1 – 0.2 $mg{\cdot}L^{-1}$	
Copper	0.2 $mg{\cdot}L^{-1}$	0.08 – 0.15 $mg{\cdot}L^{-1}$	
Molybdenum	0.07 $mg{\cdot}L^{-1}$	0.02 – 0.05 $mg{\cdot}L^{-1}$	
Sulfate	240 $mg{\cdot}L^{-1}$	24 – 240 $mg{\cdot}L^{-1}$ (60 to 90 $mg{\cdot}L^{-1}$)	If the concentration is less than about 50 ppm, supplemental sulfate may need to be applied for good plant growth. High concentrations of sulfides can lead to build-up of sulfur-bacteria in irrigation lines that could clog emitters.
Chloride	70 $mg{\cdot}L^{-1}$	0 – 50 $mg{\cdot}L^{-1}$	Concern, above 30 $mg{\cdot}L^{-1}$ for sensitive plants
Sodium	50 $mg{\cdot}L^{-1}$	0 – 30 $mg{\cdot}L^{-1}$	If the SAR is less than 2 $mg{\cdot}L^{-1}$ and sodium is less than 40 $mg{\cdot}L^{-1}$, then sodium should not limit calcium and magnesium availability

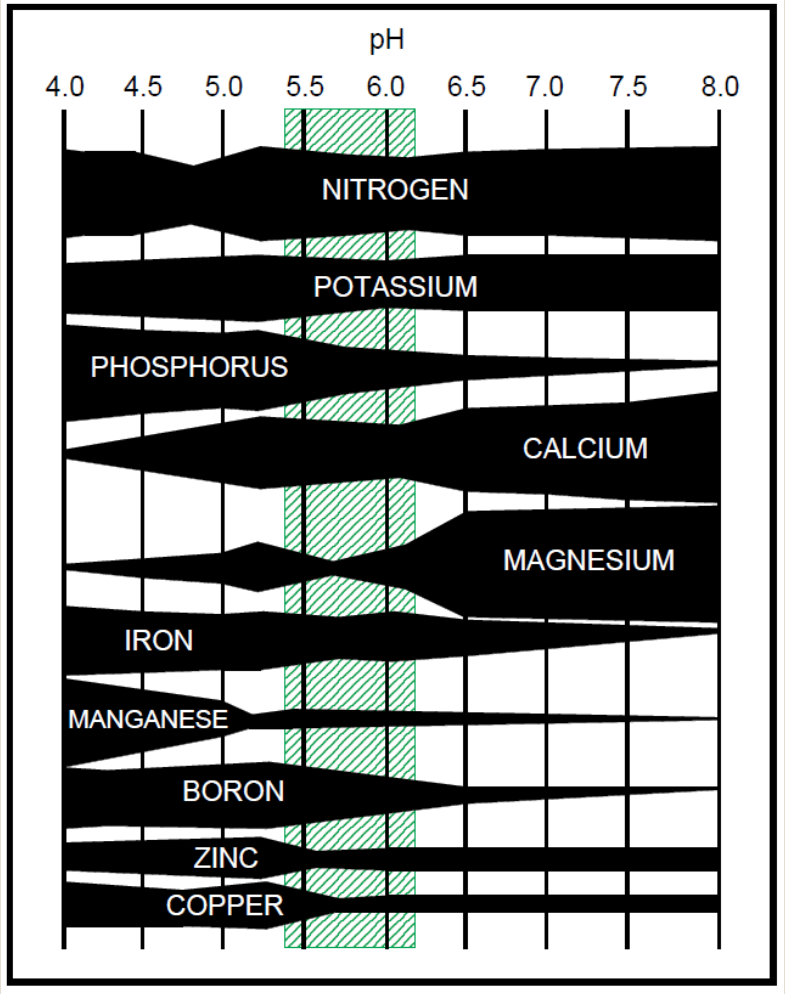
$mg{\cdot}L^{-1}$ = ppm

Chemical Properties of Growing Media

Materials	Average	Range
Wood fibre	4.8	3.8–5.4
Expanded clay granules	8.1	7.7–8.6
Coir chips	5.7	5.4–6.1
Coir dust	6.2	6.0–6.7
Perlite	6.3	5.2–7.7
PU-foam	6.6	4.7–8.9
Pumice	6.3	4.7–7.6
Rock wool	6.2	5.2–7.8
Peat	3.9	3.4–4.4

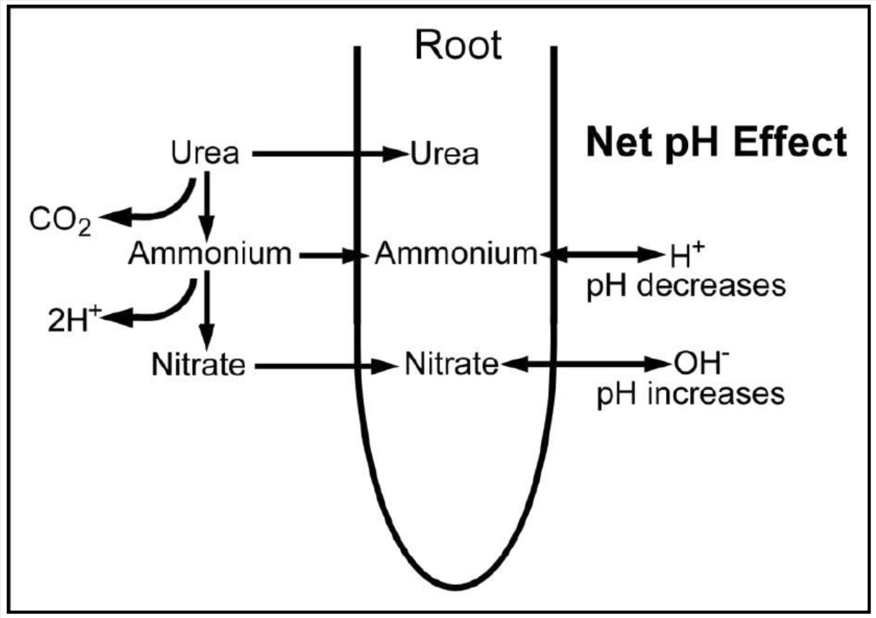
Table 11.9 The pH of different substrates and substrate constituents as given by Kipp et al. (2000)

- pH Controls the availability of all essential plant nutrients
- pH range 5.4 – 6.0 for solution culture and soilless media
- pH range 6.2 – 6.0 for soil-based media
- Too high pH: caused by highly alkaline water, excess lime, calcium nitrate fertilizers
  - P, Fe, Mn, Zn, Cu and B tied up
- Too low pH: Caused by acid forming fertilizers NH_4^+
  - Ca, Mg, S, Mo tied up. Excessively soluble Fe, Mn, and Al react with P to render it insoluble



Greenhouse substrate and management, D.A. Bailey, W.C. Fonteno and P.V. Nelson, NCSU

Selection of Fertilizer



- Proportion of potassium (K_2O:N)
- Proportion of phosphate (N:P_2O)
- Form of Nitrogen
  - Ammonium (NH_4^+), small amounts
  - Nitrate (NO_3^-), majority
  - Urea, small amounts
- Nitrate nitrogen tend to have basic reaction, raising media pH
- Ammonium sources of nitrogen will have an acid reaction, lowering media pH
- In an acidic environment NO_3^- is more readily absorbed, while NH_4^+ is better absorbed at a higher pH
- At pH 6.8, both ionic species are taken up equally

Ammonium and Nitrate Nitrogen Calculation

GUARANTEED ANALYSIS	21-5-20
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)	0.105%
0.105% 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

Answer

((7.3+1.1)/21) x 100 = 40% ammonium

(12.6/21) x 100 = 60% nitrate

WEIGHT (IN OUNCES) OF PRODUCT NEEDED TO MIX ONE GALLON OF CONCENTRATE

Target Fertilizer Concentration (N/ppm) After Dilution	Common Injector Ratios					EC (mmhos/cm) of Target Feed Rate After Dilution
	1:15	1:100	1:128	1:200	1:300	
25	0.2	1.6	2.1	3.2	4.8	0.16
50	0.5	3.2	4.1	6.4	9.6	0.32
75	0.7	4.8	6.2	9.6	14.5	0.47
100	1.0	6.4	8.2	12.9	19.3	0.63

Nitrogen Fertilizer and pH Relationship

PRODUCT PROPERTIES	
Potential Acidity	1518 lbs calcium carbonate equivalent per ton
Conductivity of 100 ppm N	0.52 mmhos/cm
Maximum Solubility	4 lbs/gal

GUARANTEED ANALYSIS	21-7-7
Total nitrogen (N)	21%
10.4% ammoniacal nitrogen	
10.6% urea nitrogen	

PRODUCT PROPERTIES	
Potential Basicity	131 lbs calcium carbonate equivalent per ton
Conductivity of 100 ppm N	0.69 mmhos/cm
Maximum Solubility	3 lbs/gal

GUARANTEED ANALYSIS	15-5-15
Total nitrogen (N)	15%
1.1% ammoniacal nitrogen	
11.8% nitrate nitrogen	
2.1% urea nitrogen	

- Potential acidity (lbs $CaCO_3$ to neutralize acidity produced by fertilizer); indicates a **likely DECREASE in substrate pH**
- Potential basicity (limestone needed to equal the acid neutralizing power of the fertilizer); indicates a **likely INCREASE in substrate pH**
- Alternating fertilizers may help to stabilize

Nitrogen Fertilizer and pH Relationship

Fertilizer	NO_3	NH_4 [b]	Potential acidity [c] or basicity [d]
Ammonium sulfate	0	100	2200 a
Urea	0	100	1680 a
21-7-7 acid	0	100	1539 a
21-7-7 acid	0	100	1518 a
Diammonium phosphate	0	100	1400 a
Ammonium nitrate	51	49	1220 a
Monoammonium phosphate	0	100	1120 a
18-9-18	47.7	53.3	708 a
20-20-20	27.5	72.5	532 a
21-5-20	62.3	37.7	407 a
20-10-20	59.5	40.5	404 a
20-10-20	60	40	401 a
21-5-20	60	40	390 a
17-5-17	70.6	29.4	106 a
20-0-20	54	46	0
15-0-20	76.7	23.3	38 b
15-5-15	80	20	69 b
15-5-15	78.7	21.3	131 b
15-0-14	82.7	17.3	165 b
15-0-15	86.7	13.3	221 b
15-0-15	80.8	18.8	319 b
Calcium nitrate	100	0	400 b
Potassium nitrate	100	0	520 b
Sodium nitrate	100	0	580 b

[a] Table adapted and revised from Paul Nelson: Greenhouse Operation and Management. p. 315. 6th ed. Prentice Hall. New Jersey.
[b] The percentage of total N in the ammonium plus urea forms; remaining N is nitrate
[c] Potential acidity is defined as the pounds of calcium carbonate limestone required to neutralize the acidity of 1 ton of fertilizer
[d] Potential basicity: applying 1 ton of this fertilizer has the pH neutralizing effect of this many pounds of calcium carbonate limestone

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Fertilizer Options for the Grower

- One-part mixes (All-Purpose)
  - Provide all the required nutrients in one bag
  - Pick desired concentration and measure out the required amount
  - Usually not for stock solutions, unless label says otherwise
- Two or three-part mixes, two stock tanks (Base plus Customizing)
  - N-P-K mix, $CaNO_3$, $MgSO_4$
  - Using two tanks, a concentrated stock solution can be made (no precipitation)
  - Tank A – calcium and chelated iron
  - Tank B – phosphates and sulfates
  - Separate tank for acid or add to Tank B
- Many-part mixes
  - Individual compound fertilizers can be used to formulate your own mix
  - Grower has full control over formulation
  - Cost effective for huge operations
  - Up to 11 fertilizers mixed and stored separately
- Liquid blends
  - Hobbyists
  - Easy to prepare but higher shipping costs

Common Nutrient Ranges in Nutrient Solutions

Element	Ionic form absorbed by plants	Common range (ppm=mg/l)
Nitrogen	Nitrate ($NO3^-$), Ammonium ($NH4^+$)	100-250 ppm elemental N
Phosphorus	Dihydrogen phosphate ($H2PO4^-$) Phosphate ($PO4^{3-}$) Monohydrogen phosphate ($HPO4^{2-}$)	30-50 ppm elemental P
Potassium	Potassium (K^+)	100-300 ppm
Calcium	Calcium (Ca^{2+})	80-140 ppm
Magnesium	Magnesium (Mg^{2+})	30-70 ppm
Sulfur	Sulfate ($SO4^{2-}$)	50-120 ppm elemental S
Iron	Ferrous ion (Fe^{2+}) Ferric ion ($Fe3^+$)	1-5 ppm
Copper	Copper (Cu^{2+})	0.04-0.2 ppm
Manganese	Manganese (Mn^{2+})	0.5-1.0 ppm
Zinc	Zinc (Zn^{2+})	0.3-0.6 ppm
Molybdenum	Molybdate ($MoO4^{2-}$)	0.04-0.08 ppm
Boron	Boric acid (H3BO3) Borate ($H2BO3^-$)	0.2-0.5 ppm elemental B
Chloride	Chloride (Cl^-)	<75 ppm
Sodium	Sodium (Na^+)	<50 ppm TOXIC to plants

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Nutrient Solution Recipes: Open vs. Closed Systems

	Macronutrients (ppm)							Micronutrients (ppm)						EC ($mS{\cdot}cm^{-1}$)
	NH_4	K	Ca	Mg	NO_3	P	SO_4	Fe	Mn	Zn	B	Cu	Mo	
Open Systems														
Lettuce	9.8	379.5	116	12.1	140.0	31.0	96.0	1.00	0.55	0.25	0.30	0.05	0.05	**1.30**
Tomato	14.0	273.0	170	42.4	175.0	46.5	288.0	0.85	0.55	0.30	0.30	0.05	0.05	**2.00**
Cucumber	14.0	379.5	150	30.3	182.0	31.0	120.0	0.85	0.55	0.30	0.30	0.05	0.05	**1.65**
Pepper	4.2	358.8	180	42.4	179.2	37.2	192.0	0.85	0.55	0.30	0.30	0.05	0.05	**1.80**
Closed Systems														
Lettuce	8.4	152.1	76	7.3	98.0	24.8	52.8	1.00	0.55	0.25	0.30	0.05	0.05	**0.89**
Tomato	11.2	187.2	86	26.6	124.5	37.2	124.8	0.85	0.55	0.24	0.20	0.05	0.05	**1.21**
Cucumber	11.2	175.5	106	21.8	134.4	31.0	86.4	0.85	0.55	0.30	0.30	0.05	0.05	**1.24**
Pepper	4.2	171.6	124	30.3	145.6	31.0	96.0	0.85	0.55	0.24	0.25	0.05	0.05	**1.34**

De Kreij et al. 1991 (Netherlands) and Deckers, 2004 (Belgium)

Compare

GUARANTEED ANALYSIS 5-11-26

Total Nitrogen (N)	5%
5.0% Nitrate Nitrogen	
Available Phosphate (P_2O_5)	11%
Soluble Potash (K_2O)	26%
Magnesium (Mg)	6.0%
6.0% Water Soluble Magnesium (Mg)	
Sulfur (S)	8.0%
8.0% Combined Sulfur (S)	
Boron (B)	0.05%
Copper (Cu)	0.015%
0.015% Chelated Copper (Cu)	
Iron (Fe)	0.3%
0.3% Chelated Iron (Fe)	
Manganese (Mn)	0.05%
0.05% Chelated Manganese (Mn)	
Molybdenum (Mo)	0.01%
Zinc (Zn)	0.015%
0.015% Chelated Zinc (Zn)	

Derived from: Potassium Nitrate, Magnesium Sulfate, Monopotassium Phosphate, Iron EDTA, Manganese EDTA, Boric Acid, Zinc EDTA, Copper EDTA, Sodium Molybdate

GUARANTEED ANALYSIS 5-12-26 F1313

Total nitrogen (N)	5%
5.00% nitrate nitrogen	
Available phosphate (P_2O_5)	12%
Soluble potash (K_2O)	26%
Magnesium (Mg),	6.3200%
6.3200% water soluble magnesium (Mg)	
Sulfur (S)	8.21%
8.21% combined sulfur (S)	
Boron (B)	0.0500%
Copper (Cu)	0.0150%
0.0150% chelated copper (Cu)	
Iron (Fe)	0.3000%
0.3000% chelated iron (Fe)	
Manganese (Mn)	0.0500%
0.0500% chelated manganese (Mn)	
Molybdenum (Mo)	0.0100%
Zinc (Zn)	0.0150%
0.0150% chelated zinc (Zn)	

Derived from: monopotassium phosphate, potassium nitrate, magnesium sulfate, boric acid, iron DTPA, iron EDDHA, iron EDTA manganese EDTA, zinc EDTA, copper EDTA, ammonium molybdate

Potential Basicity: 211 lbs. Calcium carbonate equivalent per ton.

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

WARNING: This product contains Molybdenum (Mo) and may be harmful to ruminant animals foraging on grass where applications have been made.

Always Compare Solution Composition

	Total	Peters Professional 5-11-26 (ppm)	Jacks Hydroponics 5-12-26 (ppm)
Nitrogen (all nitrate)	N	50	50
Phosphorus	P	48	52
Potassium	K	216	215
Magnesium	Mg	60	63
Sulfate	SO_4	80	246
Iron	Fe	3	3
Manganese	Mn	0.50	0.50
Zinc	Zn	0.15	0.15
Copper	Cu	0.15	0.15
Boron	B	0.50	0.50
Molybdenum	Mo	0.10	0.10

Lettuce, Herbs, Leafy greens

Jack's Hydro-FeEd (16-4-17)

This is a 1-bag solution; use 355 g in 100 gal. water (dilute) or for each 1 gal. in a stock tank (using a 1:100 injector)

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

Tank A	Tank B
284 g Calcium nitrate (15-0-0)	284 g 5-12-26

Modified Sonneveld's solution for lettuce

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	*0.290g $MnSO_4 \cdot H_2O$
*3.8 g 10% Iron-DTPA Sprint 330 or Sequestrene 330	*0.352g H_3BO_3
	*0.023g $Na_2MoO_4 \cdot 2H_2O$
	*0.217g $ZnSO_4 \cdot 7H_2O$
	*0.035g $CuSO_4 \cdot 5H_2O$

Source: Neil Mattson and Cari Peters. A recipe for hydroponic success. InsideGrower.

Lettuce, Herbs, Leafy greens

	Jack's Hydro-FeED (16-4-17)	Jack's Hydroponic (5-12-26) + Calcium nitrate	Modified Sonneveld's solution
Nitrogen (N)	150	150	150
Phosphorus (P)	16	39	31
Potassium (K)	132	162	210
Calcium (Ca)	38	139	90
Magnesium (Mg)	14	47	24
Iron (Fe)	2.1	2.3	1.0
Manganese (Mn)	0.47	0.38	0.25
Zinc (Zn)	0.49	0.11	0.13
Boron (B)	0.21	0.38	0.16
Copper (Cu)	0.131	0.113	0.023
Molydenum (Mo)	0.075	0.075	0.024

Source: Neil Mattson and Cari Peters. A recipe for hydroponic success. InsideGrower.

Target Nitrogen Feed Rates (ppm)

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

Solution adjustment - Tomato Nutrition, K:N ratio

- **Optimal ratio of K to N varies with growth stage**
  - When the **first truss is in flower**, the K:N ratio should be **1.2:1**, which is the same K:N requirement as in most plants during the vegetative stage
  - This ratio increases to **2:1** as the **fruit load** on the plant **increases**, since about 70% of the potassium absorbed moves into the fruit
  - By the time the **ninth cluster flowers open**, the ratio should be **2.5:1**

Tomato Nutrient Solution Recipe

Table 6. Recipe for tomatoes in winter according to crop growth stage (units are ppm).	**Weeks 0-6** **Higher N, Ca and Mg for vegetative growth**	**Weeks 6-12** **Lower N, higher K for reproductive growth**	**Week 12+** **Maintain balance of vegetative / reproductive growth**
Nitrogen (N)	224	189	189
Phosphorus (P)	47	47	39
Potassium (K)	281	351	341
Calcium (Ca)	212	190	170
Magnesium (Mg)	65	60	48
Iron (Fe)	2.00	2.00	2.00
Manganese (Mn)	0.55	0.55	0.55
Zinc (Zn)	0.33	0.33	0.33
Boron (B)	0.28	0.28	0.28
Copper (Cu)	0.05	0.05	0.05
Molydenum (Mo)	0.05	0.05	0.05

Source: Sunco, Ltd., and University of Arizona, Controlled Environment Agriculture Center, http://tinyurl.com/ljlj785/

Information Resources

University resources – Extension publications

Professional magazines

- Greenhouse Management, www.greenhousemag.com
- Greenhouse Grower, www.greenhousegrower.com
- Greenhouse Canada, www.greenhousecanada.com

Books

- Greenhouse Technology and Management, Nicolas Castilla
- Greenhouse Operation and Management, Paul V. Nelson
- Soilless Culture, Michael Raviv & J. Heinrich Leith
- Growing Media for Ornamental Plants and Turf, Kevin Handreck & Niel Black
- Plant Nutrition of Greenhouse Crops, Cees Sonneveld & Wim Voogt
- Hydroponic Food Production, Howard M. Resh
- Tomatoes, Eb Heuvelink

Trade shows and conferences

- Great Lakes Fruit, Vegetable and Farm Market Expo & Michigan Greenhouse Growers Expo – Dec 4-6, 2018, Grand Rapids MI
- Indiana Horticulture Congress, Feb 12-14, 2019, Indianapolis IN
- Indiana Small Farm Conference, Feb 28 – March 2, 2019, Danville IN
- Indoor Ag Con, April 17-19, 2019, Las Vegas NV
- Cultivate'19, July 13-16, 2019, Columbus OH

Manufacturers and distributors

(list is not complete but it's a good start):

- http://www.tunnelberries.org/single-bay-high-tunnel-manufacturers.html
- http://www.tunnelberries.org/multi-bay-high-tunnel-manufacturers.html

USDA NRCS Indiana EQIP Grant

- https://www.nrcs.usda.gov/wps/portal/nrcs/main/in/programs/financial/eqip/
- https://www.nrcs.usda.gov/wps/portal/nrcs/detail/in/technical/ecoscience/bio/?cid=nrcs144p2_068639

THANK YOU Questions?

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