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Utah Hydroponic Solutions

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UTAH HYDROPONIC SOLUTIONS

UPDATED 16 April 2024

The Utah Hydroponic solutions have been developed and refined using mass balance principles coupled with tissue analysis from studies in 25 cm deep, continuously aerated, liquid hydroponics where there is no absorption or desorption with media.

These solutions also provide guidelines for fertigation of soilless substrates, but adjustments may need to be made for tap water, and for nutrient absorption and desorption with substrates.

These solutions were optimized for greenhouse conditions with ambient CO_2 and about 40% humidity. This results in a water use efficiency of about 3 grams per liter. In high CO_2 and high humidity environments, the water use efficiency can be 6 grams per liter, so the nutrient concentration should be approximately doubled.

For a discussion of the principles underlying these solutions see:

Bugbee, B. 2004. Nutrient management in recirculating hydroponic culture. *South Pacific Soilless Culture Conference*. Doi: 10.17660/ActaHortic.2004.648.12

Langenfeld, N., Pinto, D. F., Faust, J. E., Heins, R., and Bugbee, B. 2022. Principles of nutrient and water management for indoor agriculture. *Sustainability*, 14(16), 10204. Doi: 10.3390/su141610204

If you use these solutions, please cite this reference as:

Bugbee, B. and Langenfeld, N. 2024. Utah hydroponic solutions. Digital Commons USU. 1-10. https://digitalcommons.usu.edu/cpl_nutrients/2

Table of Contents

Elemental Concentration for Dicots

Water use efficiency 3 g L^{-1} (ambient, 400 ppm CO_2)

Element	(mM)	(ppm)
NO_3^{-}*	6 + 1*	84 + 14*
P	0.4	12
K	3.6	141
Ca	1.5	60
Mg	0.8	19
S	0.8	26
Si	0.6	17

	(µM)	(ppm)
Fe	7	0.39
Mn	3	0.16
Zn	3	0.20
B	40	0.43
Cu	4	0.25
Mo	0.1	9.6 ppb
Ni	0.1	5.9 ppb
Cl	6.2	0.22
Na	21	0.49

*Additional nitrogen comes from pH control.

The pH control solution is 50 mM nitric acid and 25 mM ammonium sulfate.
Lettuce and tomato receive about 20% additional N from pH control.
With the added N from pH control the effective N is about 100 ppm.

**Sodium comes from the micronutrient chelates and the sodium molybdate.

Dicot Mixing Instructions

from stock solutions

Water use efficiency 3 g L^{-1} (ambient, 400 ppm CO_2)

UPDATED 29 March 2023

Macronutrients	Stock (M)	mL per 100 L	Final (mM)
$Ca(NO_3)_2$	1	150	1.5
KNO_3	1	200	2
KH_2PO_4	0.2	200	0.4
$MgSO_4$	0.5	160	0.8
K_2SiO_3	0.3	200	0.6
HNO_3	1	100	1

Micronutrients	Stock (mM)	mL per 100 L	Final (µM)
Fe-DTPA	25	28	7
Mn-EDTA	20	15	3
$ZnCl_2$	30	10	3
H_3BO_3	400	10	40
Cu-EDTA	20	20	4
Na_2MoO_4	1	10	0.1
$NiCl_2$	1	10	0.1

Final EC (mS cm^{-1}): **0.82**

Final pH: **6.00**

Elemental Concentration for *Cannabis*

Water use efficiency 4 g L^{-1} (elevated CO_2, about 60% relative humidity)

Element	(mM)	(ppm)
NO_3^-*	9.5 + 1.9*	133 + 27*
P	1	31
K	6.2	242
Ca	2	80
Mg	0.8	19
S	0.8	26
Si	0.6	17

	(µM)	(ppm)
Fe	7	0.39
Mn	3	0.16
Zn	3	0.20
B	40	0.43
Cu	4	0.25
Mo	0.1	9.6 ppb
Ni	0.1	5.9 ppb
Cl	6.2	0.22
Na	21	0.49

*Additional nitrogen comes from pH control.

The pH control solution is 50 mM nitric acid and 25 mM ammonium sulfate.
With the added N from pH control the effective N is about 160 ppm.

**Sodium comes from the micronutrient chelates and the sodium molybdate.

Cannabis Mixing Instructions

from stock solutions

Water use efficiency 4 g L^{-1} (elevated CO_2, about 60% relative humidity)

UPDATED 29 March 2023

Macronutrients	Stock (M)	mL per 100 L	Final (mM)
$Ca(NO_3)_2$	1	200	2
KNO_3	1	400	4
KH_2PO_4	0.2	500	1
$MgSO_4$	0.5	160	0.8
K_2SiO_3	0.3	200	0.6
HNO_3	1	150	1.5

Micronutrients	Stock (mM)	mL per 100 L	Final (µM)
Fe-DTPA	25	28	7
Mn-EDTA	20	15	3
$ZnCl_2$	30	10	3
H_3BO_3	400	10	40
Cu-EDTA	20	20	4
Na_2MoO_4	1	10	0.1
$NiCl_2$	1	10	0.1

Final EC (mS cm^{-1}): **1.8**

Final pH: **6.0**

Elemental Concentration for Monocots

(Corn, Wheat, Rice)

Water use efficiency 3 g L^{-1} (ambient CO_2)

Element	Starter		Vegetative Growth		Grain Fill	
	[mM]	[ppm]	[mM]	[ppm]	[mM]	[ppm]
N	6.5	91	6	84	3	42
P	0.05	1.5	0.4	12	0.4	12
K	2.7	127	3	141	2	102
Ca	1.5	60	No Change		0.5	20
Mg	0.8	19	No Change		0.3	7.3
S	0.8	26	No Change		0.3	9.6
Si	0.6	17	No Change		0.6	17
	[µM]	[ppm]	[µM]	[ppm]	[µM]	[ppm]
Fe	55	3.1	12	0.67	8	0.42
Mn	3	0.16	No Change		No Change	
Zn	3	0.20	No Change		No Change	
B	40	0.43	No Change		No Change	
Cu	4	0.25	No Change		No Change	
Mo	0.1	9.6 ppb	No Change		No Change	
Ni	0.1	5.9 ppb	No Change		No Change	
Cl	6.2	0.22	No Change		No Change	
Na	64	1.5	21	0.49	19	0.44

*Additional nitrogen comes from pH control.

The pH control solution is 50 mM nitric acid and 25 mM ammonium sulfate.
Plants receive about 20% additional N from pH control.
With the added N from pH control the effective N during early growth is about 100 ppm.

**Sodium comes from the micronutrient chelates and the sodium molybdate.

Monocot Mixing Instructions

from stock solutions

Water use efficiency 3 g L^{-1} (ambient CO_2)

UPDATED 20 December 2021

		Starter		Vegetative Growth		Grain Fill	
Macronutrients	**Stock (M)**	**mL per 100 L**	**Final (mM)**	**mL per 100 L**	**Final (mL)**	**mL per 100 L**	**Final (mL)**
$Ca(NO_3)_2$	1	150	1.5	150	1.5	50	0.5
KNO_3	1	200	2	200	2	100	1
KH_2PO_4	0.2	25	0.05	200	0.4	200	0.4
$MgSO_4$	0.5	160	0.8	160	0.8	60	0.3
K_2SiO_3	0.3	200	0.6	200	0.6	200	0.6
HNO_3	1	150	1.5	100	1	100	1
Micronutrients	**mM**		**µM**		**µM**		**µM**
$FeCl_3$	50	10	5	10	5	5	2.5
Fe-DTPA	25	-	-	28	7	20	5
Fe-HEDTA	250	20	50	-	-	-	-
Mn-EDTA	20	15	3	15	3	15	3
$ZnCl_2$	30	10	3	10	3	10	3
H_3BO_3	400	10	40	10	40	10	40
Cu-EDTA	20	20	4	20	4	20	4
Na_2MoO_4	1	10	0.1	10	0.1	10	0.1
$NiCl_2$	1	10	0.1	10	0.1	10	0.1
Final EC (mS cm^{-1})		1.00		0.82		0.50	
Final pH		5.00		6.00		6.00	

Stock solution preparation

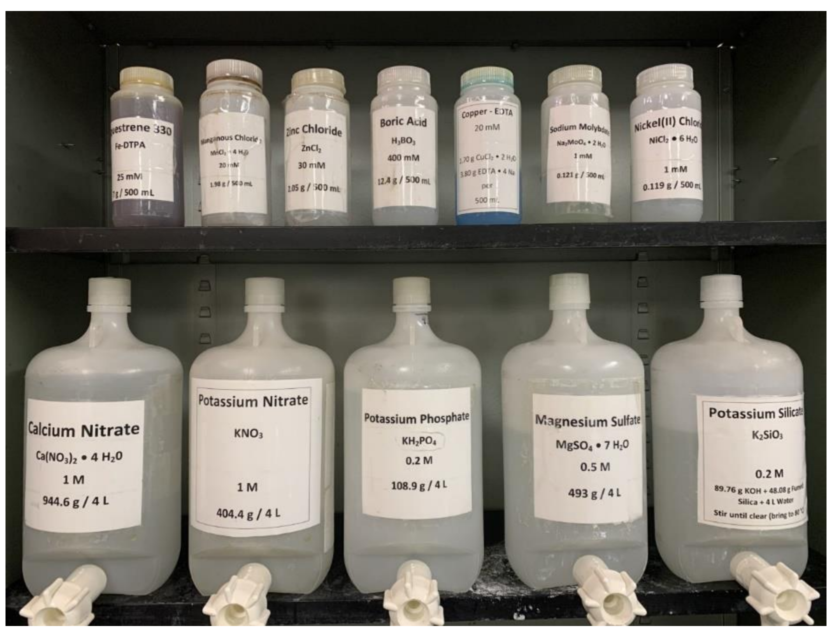
Compound	Formula	Stock (M)	g per L
Calcium nitrate tetrahydrate	$Ca(NO_3)_2 \cdot 4\ H_2O$	1	236.2
Potassium nitrate	KNO_3	1	101.1
Monopotassium phosphate	KH_2PO_4	0.2	27.2
Magnesium sulfate heptahydrate	$MgSO_4 \cdot 7\ H_2O$	0.5	123.3
Potassium silicate	K_2SiO_3	0.3	*
Nitric acid**	HNO_3	1	63.5 mL

		Stock (mM)	g per L
Iron – DTPA***	Fe-DTPA	25	14
Manganese – EDTA	Mn-EDTA	20	7.8
Zinc chloride	$ZnCl_2$	30	4.1
Boric acid	H_3BO_3	400	24.8
Copper – EDTA	Cu-EDTA	20	8
Sodium molybdate	Na_2MoO_4	1	0.238
Nickel (II) chloride	$NiCl_2$	1	0.242

*** See page 9 for potassium silicate preparation.**

**** Concentrated nitric acid (16 M) is a liquid and must be diluted with DI water to get 1 Molar acid.**

***** Iron – DTPA is derived from Sequestrene 330, which is 10% iron by mass, and 83.8% pure.**



Best practices:

- **Clearly label stock bottles.**
- **Separate macronutrients and micronutrients to reduce the chance for errors in mixing stock solutions.**
- **Store nitric acid (acidic) away from potassium silicate (basic).**

Notes

Nitrogen

pH is automatically controlled with a pH electrode, controller, and solenoid. These add frequent, small amounts of acid to maintain steady pH. The additions are triggered every 5 to 10 minutes and add about 2 mL of acid each dose. The pH control solution is 50 mM nitric acid and 25 mM ammonium sulfate. Plants receive about 20% of their nitrogen from pH control.

Phosphorus

Phosphorus (P) concentration in the Starter solution for monocots is low to minimize Fe precipitation as $FePO_4$. This is especially important with monocots like corn. The concentration of P is less than 0.01 mM (10 µM) in field soil solution where it is continuously replenished from the solid phase.

Potassium Silicate – Reagent Grade

Potassium silicate is derived from AgSil16H, which contains 52.8% SiO_2 and 32.4% K_2O by mass. First, dissolve 20.495 g KOH per L. Then, dissolve 34.136 g of AgSil16H per L. This is equivalent to 0.3 M Si and 0.6 M K.

To make a reagent grade stock solution of potassium silicate at 0.2 M, dissolve 22.44 g KOH per liter of water. Add 12.02 g fumed silica per liter of water. Mix until dissolved/clear (~1 hr. at 80 °C or ~12 hrs. at 25 °C).

Initial pH

K_2SiO_3 is highly alkaline, causing the pH of the solution to increase. Nitric acid is used to adjust pH down to 5 in monocots to minimize iron chlorosis. Because dicots are much less sensitive to iron chlorosis, the pH is adjusted to 6.

History of changes since 2009

November 2015: Reduced Mn from 4 to 2 uM and Zn from 5 to 3 uM to reduce accumulation in plant tissue.

January 2017: Reduced Cu from 4 to 2 μM to reduce accumulation in tissue.
Reduced concentration of EDDHA stock solution to make it more soluble. Increased HEDTA from 25 to 50 μM and KH_2PO_4 from 0.02 to 0.05 mM.

June 2018: Increased boron (B) in monocot solution from 4 to 40 μM; 4 μM provides adequate B for monocots but 40 μM may not be toxic; and the vegetative and reproductive solutions are now identical. Combined monocot and dicot tables for simplicity.

July 2020: Decreased KNO_3 and increased $Ca(NO_3)_2$ to give more Ca and less K. Determined initial HNO_3 volumes. Adjusted $MgSO_4$ to provide the same concentration in initial and refill solutions.

August 2020: Changed from Sequesterene 138 to FerriPlus EDDHA to improve chelate solubility. Switched from EDDHA to DTPA to eliminate the red tint of the solution, which interferes with colorimetric analysis.

December 2020: Added Ni to solution to ensure availability. Added ammonium nitrate as a source of ammonium.

January 2021: Changed from AgSil16H to Fumed Silica as a Si source to allow reagent grade Si addition.

March 2021: Increased Mn concentration from 2 to 3 μM to increase Mn in plant tissue.

June 2021: Increased Cu concentration from 2 to 4 μM to increase Cu in solution for disease prevention.

September 2021: Removed ammonium nitrate from initial solution to minimize pH decrease in young plants.

October 2021: Changed to Cu-EDTA to buffer the concentration in solution and to minimize precipitation as copper phosphate.

December 2021: Increased Si concentration from 0.3 to 0.6 to provide more Si.

April 2022: Changed to Mn-EDTA to buffer the concentration of Mn in solution and to minimize potential precipitation.

March 2023: Updated the *Cannabis* solution to account for the N that is added by pH control.

April 2024: Updated to correct the chloride concentration.