5-24-2022

Utah Hydroponic Solutions

Bruce Bugbee
Utah State University, bruce.bugbee@usu.edu

Noah Langenfeld
Utah State University, noah.langenfeld@usu.edu

UTAH HYDROPONIC SOLUTIONS

UPDATED 24 May 2022

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 irrigation of soilless substrates, but adjustments may need to be made to account for the significant cation exchange capacity and thus nutrient absorption and desorption with the 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 higher humidity environments, the water use efficiency can be 6 grams per Liter, so the nutrient concentration should be approximately doubled.

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Elemental Concentration for Dicots

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

Element	[mM]	[ppm]
*NO_3^-	6 + 1*	84 + 16*
P	0.4	12
K	3	117
Ca	1.5	60
Mg	0.8	19
S	0.8	26
Si	0.6	17

	[μM]	[ppm]
Fe	7	0.4
Mn	3	0.2
Zn	3	0.2
B	40	0.4
Cu	4	0.3
Cl	35	1.2
Mo	0.1	9.6 ppb
Ni	0.1	5.9 ppb

* 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.

Dicot Mixing Instructions

from stock solutions

Water use efficiency 3 g L^{-1}

UPDATED 4 April 2022

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	0.2	300	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: **5.80**

Elemental Concentration for *Cannabis*

Water use efficiency 4 g L^{-1} (elevated CO_2)

Element	[mM]	[ppm]
*NO_3^-	10.8	151
P	1	31
K	6.2	242
Ca	3	120
Mg	0.8	19
S	0.8	26
Si	0.6	17

	[μM]	[ppm]
Fe	7	0.4
Mn	3	0.2
Zn	3	0.2
B	40	0.4
Cu	4	0.3
Cl	35	1.2
Mo	0.1	9.6 ppb
Ni	0.1	5.9 ppb

Cannabis Mixing Instructions

from stock solutions

Water use efficiency 4 g L^{-1} (elevated CO_2)

UPDATED 24 May 2022

Macronutrients	Stock (M)	mL per 100 L	Final (mM)
$Ca(NO_3)_2$	1	300	3
KNO_3	1	400	4
KH_2PO_4	0.2	500	1
$MgSO_4$	0.5	160	0.8
K_2SiO_3	0.2	300	0.6
HNO_3	1	80	0.8

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: **6.3**

Elemental Concentration for Monocots

(Corn, Wheat, Rice)

Water use efficiency 3 g L^{-1}

	STARTER		VEGETATIVE REFILL		GRAIN-FILL REFILL	
Element	[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	104	3	117	2	78
Ca	1.5	60	No Change		0.5	20
Mg	0.8	19			0.3	7.3
S	0.8	26			0.3	9.6
Si	0.6	17			0.6	17
	[µM]	[ppm]	[µM]	[ppm]	[µM]	[ppm]
Fe	55	3.1	10	0.6	8	0.4
Mn	3	0.2	No Change			
Zn	3	0.2				
B	40	0.4				
Cu	4	0.3				
Cl	35	1.2				
Mo	0.1	9.6 ppb				
Ni	0.1	5.9 ppb				

* 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 total effective N during early growth is about 100 ppm.

Monocot Mixing Instructions

from stock solutions

Water use efficiency 3 g L^{-1}

UPDATED 20 December 2021

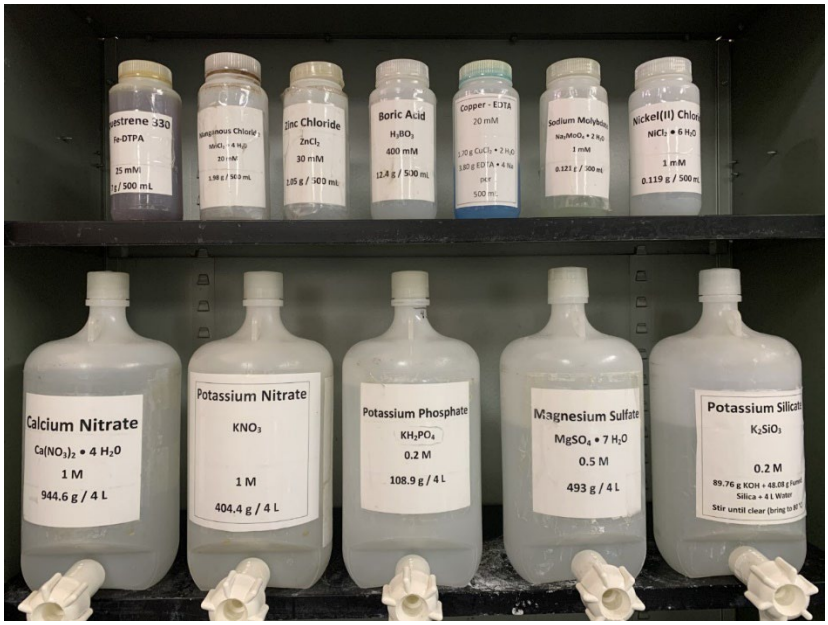
		Starter		Vegetative Growth		Grain Fill	
Macronutrients	**Stock (M)**	**mL per 100 L**	**Final (mM)**	**mL per 100 L**	**Final (mL)**	**mL per 100 L**	**Final (mL)**
$Ca(NO_3)_2$	1	150	1.5	150	1.5	50	0.5
KNO_3	1	200	2	200	2	100	1
KH_2PO_4	0.2	25	0.05	200	0.4	200	0.4
$MgSO_4$	0.5	160	0.8	160	0.8	60	0.3
K_2SiO_3	0.2	300	0.6	300	0.6	300	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		0.82		0.50	
Final pH		5.00		5.80		5.80	

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	0.2	*
Nitric acid**	HNO_3	1	63.5 mL

		Stock (mM)	g per L
Iron – DTPA***	Fe-DTPA	7	17
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	10
Nickel (II) chloride	$NiCl_2$	1	10

*** Potassium silicate is prepared as described on page 8.**
**** Concentrated nitric acid (16 M) is a liquid and must be diluted into 1 L of water for stock preparation.**
***** Iron – DTPA is derived from Sequestrene 330, which is 10% iron by mass.**



Best practices:

- **Clearly label stock solution bottles.**
- **Separate macro and micronutrients to reduce the chance for errors in mixing stock solutions.**
- **Store nitric acid 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 min. 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 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

To make a 0.2 M stock solution, 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 and 5.8 in dicots. Dicots rarely suffer from iron chlorosis.

History of changes since 2009

November 2015: Reduced Mn and Zn concentrations by half 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 solubility. Switched from EDDHA to DTPA to remove solution color.

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 minimize Pb contamination.

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 stop pH decrease in young plants.

October 2021: Changed to Cu-EDTA 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 minimize precipitation as manganese oxides.

May 2022: Updated the *Cannabis* solution to provide more N in elevated CO_2 environments