



# Nutrient solution for rice hydroponics culture

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This represents a heavily modified Yoshida's solution. Compared to Yoshida's formulation, this solution has almost the same concentration of macro and micronutrients, but the formulation has been simplified. Key advantages:

- \* The solution is now formulated as three solutions at 1000× concentration, greatly simplifying dilution.
- \* The solution is less acidic than Yoshida's formulation, reducing the amount of hydroxide required to adjust pH.
- \* The solution eliminates Na<sup>+</sup> and almost all Cl<sup>-</sup> from the medium, allowing independent investigation of toxicities of these ions. In addition much of the K<sup>+</sup> is supplied as KOH, potentially allowing control of the Na/K ratio independently of absolute concentrations and of Cl<sup>-</sup> levels.

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## MATERIALS

[Zinc sulfate heptahydrate Sigma](#)

**Aldrich Catalog #204986**

[Manganese\(II\) chloride tetrahydrate Sigma](#)

**Aldrich Catalog #M3634**

[☒ 500g Potassium Phosphate \(Monobasic\) G-](#)

**Biosciences Catalog #RC-083**

[☒ citric acid monohydrate Sigma-](#)

**aldrich Catalog #33114**

[☒ Boric acid Bio Basic](#)

**Inc. Catalog #BB0044.SIZE.500g**

[☒ Calcium nitrate tetrahydrate Bio Basic](#)

**Inc. Catalog #CB0258.SIZE.500g**

[☒ Copper \(II\) sulfate pentahydrate Bio Basic](#)

**Inc. Catalog #CDB0063.SIZE.500g**

[☒ Iron chloride \(Ferric chloride\), hexahydrate Bio Basic](#)

**Inc. Catalog #FD0201.SIZE.250g**

[☒ Magnesium sulfate, heptahydrate, ACS Bio Basic](#)

**Inc. Catalog #MB0329.SIZE.500g**

[☒ Potassium hydroxide Bio Basic](#)

**Inc. Catalog #PB0441.SIZE.500g**

[☒ Sulfuric Acid \(H<sub>2</sub>SO<sub>4</sub>\) Contributed by users](#)

[☒ Sodium metasilicate nonahydrate Sigma](#)

**Aldrich Catalog #S4392-250G**

[☒ Ammonium sulfate Sigma](#)

**Aldrich Catalog #A5132-1KG**

[☒ Ammonium molybdate tetrahydrate Sigma](#)

**Aldrich Catalog #A7302-500G**

**Solution A, 1000× (Macro and micronutrients, minus Ca, Mg and Si)**

Common name	Formula	[Stock] (g/mol)	[Final] (M)	g/L	g/2L	Element
Sulfuric acid (5M stock, diluted from concentrated; ~18M)	H <sub>2</sub> SO <sub>4</sub>	5.00 M	0.8510	170.2mL	340.4mL	S
Ammonium sulfate	(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	132.1400	0.6753	89.23	178.46	NH <sub>4</sub> , S
Potassium phosphate monobasic	KH <sub>2</sub> PO <sub>4</sub>	136.0855	0.3225	43.89	87.77	K, P
Potassium hydroxide	KOH	56.1056	0.7020	39.39	78.77	K
Citric acid, monohydrate	C <sub>6</sub> H <sub>8</sub> O <sub>7</sub> ·H <sub>2</sub> O	210.1388	0.0708	14.87	29.750	
Ferric chloride, 6-Hydrate	FeCl <sub>3</sub> ·6H <sub>2</sub> O	270.2964	0.0356	9.62	19.250	Fe
Manganous chloride, 4-hydrate	MnCl <sub>2</sub> ·4H <sub>2</sub> O	197.9052	0.0094742	1.88	3.750	Mn
Ammonium molybdate, 4-Hydrate	(NH <sub>4</sub> ) <sub>6</sub> Mo <sub>7</sub> O <sub>24</sub> ·4H <sub>2</sub> O	1235.8577	0.0000749	0.0925	0.1851	Mo
Zinc sulfate, 7-hydrate	ZnSO <sub>4</sub> ·7H <sub>2</sub> O	287.5796	0.0001521	0.0437	0.0875	Zn
Boric acid	H <sub>3</sub> BO <sub>3</sub>	61.8330	0.0189	1.17	2.335	B
Cupric sulfate, 5-Hydrate	CuSO <sub>4</sub> ·5H <sub>2</sub> O	249.6860	0.0001553	0.0388	0.0775	Cu

#### Solution B, 1000× (Ca, nitrate)

Common name	Formula	[Stock] (g/mol)	[Final] (M)	g/L	g/2L	Element
Calcium nitrate, tetrahydrate	Ca(NO <sub>3</sub> ) <sub>2</sub> ·4H <sub>2</sub> O	236.1490	0.9978	235.62	471.25	Ca, NO <sub>3</sub>

#### Solution C, 1000× (Mg, S)

Common name	Formula	[Stock] (g/mol)	[Final] (M)	g/L	g/2L	Element
Magnesium sulfate, 7-hydrate	MgSO <sub>4</sub> ·7H <sub>2</sub> O	246.4756	1.6432	405.00	810.00	Mg,S

## Elemental comparison with Yoshida's original formulation

Nutrient	Yoshida's [Final] (mM)	Modified [Final] (mM)	Difference (mM)	Percentage of original	Fold change (x)
Na	0.322482	0.031668	-0.290814	9.82%	<b>0.098x</b>
K	1.024330	1.024482	0.000151	100.01%	1x
N	2.855149	3.346067	0.490918	117.19%	1.171x
NH <sub>4</sub>	1.427799	1.350516	-0.077283	94.59%	<b>0.945x</b>
NO <sub>3</sub>	1.427350	1.995551	0.568201	139.81%	<b>1.398x</b>
PO <sub>4</sub>	0.322482	0.322482	0.000000	100.00%	1x
SO <sub>4</sub>	3.324387	3.169730	-0.154657	95.35%	<b>0.953x</b>
Ca	0.997775	0.997775	0.000000	100.00%	1x
Mg	1.643165	1.643165	0.000000	100.00%	1x
Mn	0.009474	0.009474	0.000000	100.00%	1x
Mo	0.000524	0.000524	0.000000	100.04%	1x
Zn	0.000152	0.000152	0.000000	100.00%	0.999x
H <sub>3</sub> BO <sub>3</sub>	0.018881	0.018882	0.000000	100.00%	1x
Cu	0.000155	0.000155	0.000000	100.04%	1x
Fe	0.035609	0.035609	0.000000	100.00%	0.999x
Cl	2.130801	0.125775	-2.005025	5.90%	<b>0.059x</b>
Si	0.015834	0.015834	0.000000	100.00%	1x
Citrate		0.000071			

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The formulation makes use of 5M sulfuric acid. This is prepared by diluting concentrated sulfuric acid (~18M) to achieve the final 5M stock. Diluting strong acids is hazardous and appropriate protocols should be followed.

### Solution A, 1000x (Main macro and micronutrients)

- 1 Make this solution up as a SINGLE stock solution. For 1L of stock solution,
  - \* Start with ~600mL de-ionised water.
  - \* Weigh out and dissolve each component (except ferric chloride and citric acid) directly in the 600mL solution. Allow each to dissolve completely before adding the next.
  - \* For the KOH, add pellets slowly, a few at a time, with constant mixing.
  - \* Dissolve the citric acid separately in 100mL de-ionised water. Dissolve the ferric chloride 6-hydrate directly in the citric acid solution. Stir the ferric chloride-citrate solution for 15 minutes, then add slowly to the main stock solution while stirring.
  - \* Make up to 1L.

### Solution B, 1000x (Ca, NO<sub>3</sub>)

- 2 For 1L of stock solution, dissolve the calcium nitrate 4-hydrate directly in 700mL de-ionised water. Make up to 1L.

#### Solution C, 1000× (Mg, S)

- 3 For 1L of stock solution, dissolve the magnesium sulfate 7-hydrate in 700mL de-ionised water. Make up to 1L.

#### Solution D, 1000× (silicon)

- 4 (Optional): For 1L of stock solution, dissolve 4.50g sodium metasilicate 9-hydrate in 700mL de-ionised water. Make up to 1L.  
The sodium metasilicate can also be weighed out and dissolved directly in the growth medium at the time of preparation.

#### Preparation of hydroponics medium

- 5 For 100L of 1× hydroponics solution:
  - \* Prepare ~90L of water.
  - \* Mix in 100mL of each stock solution, mixing well before adding next stock solution.
  - \* Add sodium metasilicate 9-hydrate (0.00450g/L) and dissolve with stirring, if not done as solution D.
  - \* Adjust pH to 5.5
  - \* Dispense to growth trays.
- 6 Monitor and adjust pH of stock solution daily at pH 5.5 with KOH/HCl as required. Refresh stock solution twice per week.