Knowledge grows

Greenhouse horticulture
The Netherlands

9 & 10 March 2016
Peter de Vries
Yara International
Horticulture in The Netherlands
The Netherlands below sea level
Horticulture (in greenhouses)
How it started with grapes

Photo: PdV

Photo: PdV
And how it is 100 years later

Photo: Zwirs- Knijnenburg NL

Photo: PdV
### Total area of Greenhouse market in NL

<table>
<thead>
<tr>
<th>Year</th>
<th>ha</th>
<th>growers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>7907</td>
<td>17571</td>
</tr>
<tr>
<td>1980</td>
<td>8760</td>
<td>15772</td>
</tr>
<tr>
<td>1985</td>
<td>8973</td>
<td>14986</td>
</tr>
<tr>
<td>1990</td>
<td>9772</td>
<td>14413</td>
</tr>
<tr>
<td>2000</td>
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<td>11071</td>
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<tr>
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<td>10345</td>
</tr>
<tr>
<td>2002</td>
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<td>9876</td>
</tr>
<tr>
<td>2003</td>
<td>10539</td>
<td>9458</td>
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<tr>
<td>2004</td>
<td>10486</td>
<td>8991</td>
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<tr>
<td>2005</td>
<td>10540</td>
<td>8602</td>
</tr>
<tr>
<td>2006</td>
<td>10381</td>
<td>8020</td>
</tr>
<tr>
<td>2007</td>
<td>10374</td>
<td>7399</td>
</tr>
<tr>
<td>2008</td>
<td>10166</td>
<td>6779</td>
</tr>
<tr>
<td>2009</td>
<td>10324</td>
<td>6249</td>
</tr>
<tr>
<td>2010</td>
<td>10307</td>
<td>5782</td>
</tr>
<tr>
<td>2011</td>
<td>10249</td>
<td>5462</td>
</tr>
<tr>
<td>2012</td>
<td>9996</td>
<td>5099</td>
</tr>
<tr>
<td>2013</td>
<td>9817</td>
<td>4796</td>
</tr>
<tr>
<td>2014</td>
<td>9431</td>
<td>4415</td>
</tr>
</tbody>
</table>

**Heated greenhouses:** 92%

**Source:** 20134
- CBS (Central Bureau of Statistics)
- LEI (Agricultural-Economics Research Institute)
## Area of crops in greenhouses 2013 – 2014

### Vegetables:

- **Tomato**: 1768 ha
- **Sweet pepper**: 1244 ha
- **Cucumber**: 615 ha
- **Strawberry (incl. tunnels)**: 286 ha
- **Reddish**: 77 ha
- **Egg plant (Aubergine)**: 104 ha
- **Rest vegetables**: 769 ha

### Flowers:

- **Chrysanthemum**: 479 ha
- **Rose**: 384 ha (2014: 310 ha)
- **Orchids**: 212 ha
- **Lillie**: 189 ha
- **Gerbera**: 169 ha
- **Freesia**: 97 ha
- **Rest cut flowers**: 608 ha

### Pot plants:

- **Flowering plants**: 868 ha
- **Foliage plants**: 436 ha
- **Small garden plants**: 445 ha

### Fruit:

- **53 ha**

### Nursery:

- **483 ha**

### Rest flowers & plants:

- **508 ha**

**Source:** CBS & LEI, 2013
Area vegetables greenhouse  2000 - 2013
Some general Horticultural facts

- All growers are obligated to collect drainage water and to re-use it.
- Use of CO$_2$ is common.
- Tomato, Cucumber, Sweet Pepper, Egg plant, Roses are grown in soil less media.
- Growers think and calculate in mmol/l and µmol/l.
- Greenhouses are heated with natural gaz and highly energy efficiënt.
- Fertiliser recipe are based on water- or soil analysis and developed by Research Centre and based on growers experience.
- Growers use external consultances and Many growers are using Yara liquid fertilisers
Yara factory in The Netherlands:

Yara Vlaardingen BV
Yara Vlaardingen BV production site

- Location: Vlaardingen (The Netherlands)
- Close to Rotterdam: one of the largest port worldwide
- Product lines:
  - Solid NPK Blends
    - WS NPK unit
    - PG Mix unit
  - Liquid Blends (Substrafeed)
Yara Vlaardingen BV production site

- A global fertigation training center for
  - Yara customers, employees
  - Students, advisors, and growers

- Including a modern greenhouse
  - For demonstrations and try-outs
  - In a practical set-up

- A modern laboratory to analyze
  - All incoming raw-materials
  - Outgoing end-products

- Sampling every production run
  - Retain at least 1 year
  - All NPK fertilizers
  - And liquids fertilizers
  - To secure quality
Products and brands – Yara Vlaardingingen B.V.

Water Soluble NPK
- KRISTALON
- FERTICARE
- DELTASPRAY
- KRISTAFLEX
- FOLICARE
- ALBATROS
- locals

Micro nutrients
- TENSO Fe
- TENSO Cocktail

Liquid fertilizers
- SUBSTRAFEED
- Super FK
- Magnitra – L
- Antibloc

Potting soil fertilizers
- PG Mix
- PG Mix Super
- PG Mix Cocos
- PG micromix
WS NPK products of Yara Vlaardingen

- **100% water soluble**
  - Precipitation free fertilizer tank
  - No clogged filters/systems

- **Pure and homogenous/uniform**
  - No residue
  - No segregation
  - Possibility to dosage ½ or ¼ bags.

- **Free flowing/non caking, free of dust**
  - Fast and easy to handle
  - Clean to use
Soil cultivation versus substrate
<table>
<thead>
<tr>
<th></th>
<th>Soil</th>
<th>Substrate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Root volume</strong></td>
<td>&gt; 500 l/m²</td>
<td>&lt; 15 l/m²</td>
</tr>
<tr>
<td><strong>2. Nutrient storage &amp; stock</strong></td>
<td>&gt; 50% (tomato)</td>
<td>&lt; 5% (tomato) needed</td>
</tr>
<tr>
<td><strong>3. Trace elements:</strong></td>
<td>often present</td>
<td>needed</td>
</tr>
<tr>
<td><strong>4. Buffering capacity (CEC)</strong></td>
<td>often present</td>
<td>does not occur</td>
</tr>
<tr>
<td><strong>5. pH</strong></td>
<td>depends on soil</td>
<td>depends on grower</td>
</tr>
<tr>
<td><strong>6. Ammonium (NH₄⁺)</strong></td>
<td>depends on soil</td>
<td><strong>Highly</strong> sensitive</td>
</tr>
<tr>
<td><strong>7. Urea</strong></td>
<td>allowed</td>
<td><strong>Not</strong> allowed</td>
</tr>
<tr>
<td><strong>8. Salination</strong></td>
<td>less sensitive</td>
<td>highly sensitive</td>
</tr>
<tr>
<td><strong>9. Calcium (Ca²⁺)</strong></td>
<td>often beneficial</td>
<td>absolutely needed!</td>
</tr>
</tbody>
</table>
Fertilization manuals
**Goal:** to determine the current nutrient situation and/or to predict the nutrient situation in the future.

All recommendations are always based on analysis.

A soil, water or tissue sample must be a representative sample, to obtain reliable results and fertilizer recommendations.

An analysis is an assurance, it could prevent mistakes and saves money!

Source: BLGG laboratories The Netherlands
Fertilisation Advice-standard for Substrates an Soil.

The Dutch fertilisation standard
Developed by Wageningen University Research (WUR) in cooperation with the horticulture.

ISSN 1387 – 2427 May 1999

Vegetables and flowers in
- Rock wool, peat, coco
- Crops in Greenhouse soil

Other standards:
- Pot plants
- Open field flowers

Source: WUR/PPO The Netherlands
## Open access at library.wur.nl

### Library Catalogue

- **Record number**: 947941
- **Title**: Bemestingsadviesbasis substraten
- **Author(s)**: Kreij, C. de; Vooigt, W.; Bos, A.L. van den
- **Publisher**: Naaldwijk: Proefstation voor Bloemisterij en Glasgroente, Vestiging Naaldwijk
- **Publication year**: 1999
- **Description**: 145 p.
- **Keyword(s)**: nutrients; substrates; directives; netherlands; fertilizer requirement determination; soil analysis
- **Categories**: Fertilizers, Fertilizer Application
- **Publication type**: Monograph
- **Language**: Dutch; Flemish
- **Availability**: FORUM; BOOKS; 502-P-4/1999-03; GLAS; OK; F3-Kre; INTERNET;

### Comments

There are no comments yet. You can post the first one! [Post a comment](#)
**Fertilisation Advice-standard for Substrates (PPO)**

**Crop:** Tomato

**Free drainage**

**Crop: Tomato**

**Free drainage**

**Standard solution**

**Target values**

**Interpretation of the analysis**

**Limits for corrections**

**Corrections**

**Correction of pH with NH$_4^+$**

### Standard EC drip water

<table>
<thead>
<tr>
<th>Element</th>
<th>NH$_4^+$</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>NO$_3$</th>
<th>SO$_4$</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laag</td>
<td>&lt; 6.5</td>
<td>8.0</td>
<td>2.7</td>
<td>17.0</td>
<td>2.5</td>
<td>4.0</td>
<td>0.70</td>
</tr>
<tr>
<td>Hoog</td>
<td>&gt; 0.5</td>
<td>10.0</td>
<td>12.0</td>
<td>6.5</td>
<td>28.0</td>
<td>12.0</td>
<td>9.0</td>
</tr>
<tr>
<td>Buiten A.V.W.</td>
<td>&lt; 3.5</td>
<td>4.5</td>
<td>1.4</td>
<td>7.0</td>
<td>1.7</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>*</td>
<td>&gt; 2.0</td>
<td>16.0</td>
<td>10.0</td>
<td>20.0</td>
<td>9.0</td>
<td>34.0</td>
<td>20.0</td>
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</tbody>
</table>

### Standard EC target value

<table>
<thead>
<tr>
<th>Element</th>
<th>NH$_4^+$</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>NO$_3$</th>
<th>SO$_4$</th>
<th>P</th>
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</thead>
<tbody>
<tr>
<td>Laag</td>
<td>&lt; 6.5</td>
<td>8.0</td>
<td>2.7</td>
<td>17.0</td>
<td>2.5</td>
<td>4.0</td>
<td>0.70</td>
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<tr>
<td>Hoog</td>
<td>&gt; 0.5</td>
<td>10.0</td>
<td>12.0</td>
<td>6.5</td>
<td>28.0</td>
<td>12.0</td>
<td>9.0</td>
</tr>
<tr>
<td>Buiten A.V.W.</td>
<td>&lt; 3.5</td>
<td>4.5</td>
<td>1.4</td>
<td>7.0</td>
<td>1.7</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>*</td>
<td>&gt; 2.0</td>
<td>16.0</td>
<td>10.0</td>
<td>20.0</td>
<td>9.0</td>
<td>34.0</td>
<td>20.0</td>
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</table>

### Interpretation of the analysis

<table>
<thead>
<tr>
<th>HCO$_3$</th>
<th>EC</th>
<th>Ca</th>
<th>Mg</th>
<th>NO$_3$</th>
<th>SO$_4$</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laag</td>
<td>&lt; 2.5</td>
<td>3.0</td>
<td>5.0</td>
<td>35.0</td>
<td>10.0</td>
<td>65.0</td>
</tr>
<tr>
<td>Hoog</td>
<td>&gt; 1.0</td>
<td>5.0</td>
<td>6.5</td>
<td>35.0</td>
<td>10.0</td>
<td>65.0</td>
</tr>
<tr>
<td>Buiten A.V.W.</td>
<td>&lt; 1.5</td>
<td>6.0</td>
<td>7.5</td>
<td>75.0</td>
<td>20.0</td>
<td>50.0</td>
</tr>
<tr>
<td>*</td>
<td>&gt; 2.0</td>
<td>8.0</td>
<td>7.5</td>
<td>75.0</td>
<td>20.0</td>
<td>50.0</td>
</tr>
</tbody>
</table>

* Geen correctie ECs ** HCO$_3$ < 0.5 *** HCO$_3$ > 0.5

**Opm. 1, 2, 3, 4, 6.**

Voor de betekenis van de nummers: zie onder ‘opmerkingen’ in hoofdstuk 3

### Limits for corrections

<table>
<thead>
<tr>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>NO$_3$</th>
<th>SO$_4$</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
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<td>&lt; 6.0</td>
<td>&lt; 6.0</td>
<td>&lt; 14.0</td>
<td>&lt; 4.0</td>
<td>&lt; 0.70</td>
</tr>
<tr>
<td>2</td>
<td>5.0-6.4</td>
<td>6.0-7.9</td>
<td>&gt; 2.7</td>
<td>14.0-16.9</td>
<td>&lt; 4.0</td>
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<tr>
<td>3</td>
<td>6.5-10.0</td>
<td>8.0-12.0</td>
<td>&gt; 2.7-6.5</td>
<td>17.0-28.0</td>
<td>4-9.0</td>
</tr>
<tr>
<td>4</td>
<td>10.1-13.0</td>
<td>12.1-15.0</td>
<td>&gt; 6.6</td>
<td>28.1-32.0</td>
<td>&gt; 9.0</td>
</tr>
<tr>
<td>5</td>
<td>&gt; 13.0</td>
<td>&gt; 15.0</td>
<td>&gt; 30.0</td>
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### Corrections

<table>
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<tr>
<th>Fe</th>
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<th>Zn</th>
<th>B</th>
<th>Cu</th>
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<td>&lt; 3.0</td>
<td>&lt; 15.0</td>
<td>&lt; 0.3</td>
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<tr>
<td>2</td>
<td>15.0-17.9</td>
<td>&lt; 3.0</td>
<td>3.0-4.9</td>
<td>15.34</td>
</tr>
<tr>
<td>3</td>
<td>18.0-36.0</td>
<td>3.0-10.0</td>
<td>5.0-10.0</td>
<td>35.0-45.0</td>
</tr>
<tr>
<td>4</td>
<td>35.1-50.0</td>
<td>10.1-15.0</td>
<td>10.1-15.0</td>
<td>65.0-90.0</td>
</tr>
<tr>
<td>5</td>
<td>&gt; 50.0</td>
<td>&gt; 15.0</td>
<td>&gt; 15.0</td>
<td>&gt; 9.0</td>
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</tbody>
</table>

### Aanpassingen

<table>
<thead>
<tr>
<th>Hoofdelementen in mmol/l</th>
<th>Spoorzwaluwelen in %</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>3.0</td>
</tr>
<tr>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>1.5</td>
</tr>
<tr>
<td>5</td>
<td>3.0</td>
</tr>
</tbody>
</table>

* Als zoi < 6.5 aanpassing is 0.5 mmol

### Extra aanpassing

<table>
<thead>
<tr>
<th>Ammonium aanpassing</th>
</tr>
</thead>
<tbody>
<tr>
<td>factor K/Ca &gt; 1.1</td>
</tr>
<tr>
<td>Analyse-lijst</td>
</tr>
<tr>
<td>6</td>
</tr>
</tbody>
</table>

### Combinatieklasse

<table>
<thead>
<tr>
<th>extra NH$_4$NO$_3$</th>
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<tbody>
<tr>
<td>K</td>
</tr>
<tr>
<td>8.5-10.0</td>
</tr>
<tr>
<td>Aanpassing</td>
</tr>
<tr>
<td>* 0.25 K</td>
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</table>

Source: WUR/PPO The Netherlands
Fertilisers
# Solubility: different products and solubility

## Yara Fertilizers - Solubility, pH and EC

<table>
<thead>
<tr>
<th>Solubility at °C (g/l)</th>
<th>°C</th>
<th>Calcinit</th>
<th>Krista K</th>
<th>Krista MKP</th>
<th>Krista MAP</th>
<th>Krista MgS</th>
<th>Krista SOP</th>
<th>Krista MAG</th>
<th>Krista UP</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>956</td>
<td></td>
<td></td>
<td>227</td>
<td></td>
<td>70</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td></td>
<td>133</td>
<td>110</td>
<td>255</td>
<td></td>
<td>80</td>
<td>680</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>1000</td>
<td>170</td>
<td>180</td>
<td>295</td>
<td></td>
<td>90</td>
<td>790</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>1055</td>
<td></td>
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<td></td>
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<td>700</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>1100</td>
<td>315</td>
<td>230</td>
<td>374</td>
<td>750</td>
<td>124</td>
<td>710</td>
<td>960</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>1170</td>
<td></td>
<td>250</td>
<td>410</td>
<td></td>
<td></td>
<td>720</td>
<td></td>
</tr>
<tr>
<td>Effect in solution (1% w/w)</td>
<td>pH</td>
<td>6,0</td>
<td>8-9</td>
<td>4,5</td>
<td>5,6</td>
<td>6,6</td>
<td>5,6</td>
<td>6,5</td>
<td>1,8</td>
</tr>
<tr>
<td></td>
<td>EC</td>
<td>1,2</td>
<td>1,3</td>
<td>0,7</td>
<td>0,7</td>
<td>0,7</td>
<td>1,54</td>
<td>0,88</td>
<td>1,5</td>
</tr>
</tbody>
</table>

The table above provides the solubility of different fertilizers at various temperatures and the effect in solution at 1% w/w concentration. The **pH** and **EC** values are also included for reference.
Solubility of Phosphate salts

Phosphate solubility depends on pH:

- $\text{Ca(H}_2\text{PO}_4\text{)}_2$ 20 g/l
- $\text{CaHPO}_4$ 0,2 g/l
- $\text{Ca}_3(\text{PO}_4)_2$ 0,02 g/l
- $\text{MgHPO}_4.\text{7H}_2\text{O}$ 3 g/l

Other low soluble salts:
Gypsum: $\text{CaSO}_4$ 2,3 g/l
Iron phosphate
Salt solubility: A + B tank

Prevent precipitation with S and P
Use an A – B tank system:
  • **Tank A:** Calcium
  • **Tank B:** S and P

\[
\text{Ca} + S \rightarrow \text{Gypsum}
\]

**Maximum concentration:**
in general: 100x

Concentration depends on:
  • Temperature
  • Composition
Straight fertilisers in substrate

A tank

Calcium, NO₃, (NH₄)

B tank

Krista K plus
Krista MKP
Krista MgS
Krista SOP
Krista MAG
Micro nutrients

NO₃, (NH₄), Phosphate, K, Mg and Sulfur
Micro nutrients: Fe, Mn, Zn, B, Cu, Mo

Never mix Calcium with Sulfur and Phosphate in one concentrated solution.
Recipe, dosage and formula depends of crop and other local conditions.
The stock solution must be diluted to the optimal EC, depending of the crop, local conditions, etc.
WS NPK in substrate

A tank

**Calcium, NO₃, (NH₄)**

B tank

**NO₃, (NH₄), Phosphate, K, Mg and Sulfur**

Micro nutrients: Fe, Mn, Zn, B, Cu, Mo

Use only special developed ws-NPK for substrate

Never mix Calcium with Sulfur and Phosphate in one concentrated solution.

Recipe, dosage and formula depends of crop and other local conditions.

The stock solution must be diluted to the optimal EC, depending of the crop, local conditions, etc.
Optimal pH stock solution tanks

A – tank (Calcium containing tank)
- Fe-DTPA pH 2,0 – 6,0
- Fe-EDDHA – HBED pH 3,5 – 6,0

B – tank (Sulfur and/or Phosphate containing tank)
- General < pH 5,0
- Mn-EDTA pH 3,5 – 5,0
- Zn-EDTA pH 2,0 – 5,0
- Cu-EDTA pH 2,0 – 5,0

When pH is very low in tank, check pH drip water (pH alarm “on”)
Optimal pH of drip water

General pH range drip water: pH 5,0 – 6,2
Optimal pH depends of crop, substrate and other local conditions.

When pH is too high: above > 6,2:
High risk of precipitation and clogging of drippers filters, etc. caused by:
- Calcium phosphate
- Magnesium phosphate
- Iron phosphate.

When pH is too low: below < 5,0:
- Too acid for plant-roots.
- Rock wool start to dissolve.
Water quality, acid and ammonium
# Water quality

## Water quality for horticultural use

<table>
<thead>
<tr>
<th></th>
<th>Standard 1</th>
<th>Standard 2</th>
<th>Standard 3</th>
<th>Standard 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC</td>
<td>&lt; 0.5</td>
<td>&lt; 1.0</td>
<td>&lt; 1.5</td>
<td>&gt; 1.5</td>
</tr>
<tr>
<td>Na⁺</td>
<td>&lt; 1.5 (&lt;35)</td>
<td>&lt; 3.0 (&lt;69)</td>
<td>&lt; 4.5 (&lt;104)</td>
<td>&gt; 4.5 (&gt;104)</td>
</tr>
<tr>
<td>Cl⁻</td>
<td>&lt; 1.5 (&lt;53)</td>
<td>&lt; 3.0 (&lt;106)</td>
<td>&lt; 4.5 (&lt;160)</td>
<td>&gt; 4.5 (&gt;160)</td>
</tr>
</tbody>
</table>

**Standard 1.**
Water quality is suitable for most crops, or can be made suitable for all purposes of irrigation.

**Standard 2.**
Intermediate water quality. Not suitable for crops with limited root volume (hydroponics, pot plants), which cannot be flushed with sufficient water during the season.

**Standard 3.**
The water quality is not suitable for irrigation of salt sensitive crops, and also less salt sensitive crops with limited root volume (hydroponics, pot plants).

**Standard 4.**
The water is not suitable for crops in greenhouses. Irrigation with this water quality could decrease the yield or the quality of the crop. When using this water quality, it is essential to frequently flush the soil to prevent accumulation of salt.

Source: PPO Naaldwijk The Netherlands
Maximum Na levels in root zone (in soil less – substrate systems)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Max. Na (mmol/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomato</td>
<td>8</td>
</tr>
<tr>
<td>Sweet pepper, Egg plant</td>
<td>6</td>
</tr>
<tr>
<td>Cucumber, Melon</td>
<td>6</td>
</tr>
</tbody>
</table>

Source: WUR/PPO The Netherlands

Figure salinity: free according Sonneveld (1991).
Na and Cl levels in closed systems

- Na is a negative element and disturbers the uptake of e.g. water and K
- Cl is in general less negative compared Na. (Cl is sometimes a real nutrient)
- Na must be as low as possible, especially in closed systems.
- Maximum level depends on maximum uptake of the crop.

<table>
<thead>
<tr>
<th>Crop</th>
<th>max. Na (mmol/l)</th>
<th>max. Cl (mmol/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet pepper, Egg plant</td>
<td>0,2</td>
<td>0,4</td>
</tr>
<tr>
<td>Cucumber, Melon</td>
<td>0,5</td>
<td>0,7</td>
</tr>
<tr>
<td>Tomato</td>
<td>0,7</td>
<td>0,9</td>
</tr>
</tbody>
</table>

Source: WUR/PPO The Netherlands
Hard water is not a problem: use acid

Example:
HCO₃⁻ 250 ppm = 4.1 mmol/l  
Ca 87.4 ppm = 2.2 mmol/l  
Mg 9.2 ppm = 0.4 mmol/l  
S 14.1 ppm = 0.4 mmol/l

Hard water + Nitric acid:
→ Ca + Mg + HCO₃⁻ + H⁺ + NO₃⁻
→ Ca + Mg + CO₂ + H₂O + NO₃⁻
→ Ca + Mg + NO₃⁻

Hard water contains nutrients for free!
Bicarbonate must be neutralized with acid.
How to lower the pH?

**Use acids (H⁺) to lower the pH of the water**
- Process: Chemical acidifying, fast reaction:
  - $\text{HCO}_3^- + \text{HNO}_3 \rightarrow \text{H}_2\text{O} + \text{CO}_2 + \text{NO}_3^-$
- Acids: Nitric acid, Phosphoric acid, etc.;
- Dosage depends on water quality and acid specification;
- Dosage in B tank (without chelates);
- In A tank (max 0.5 mmol/l H⁺ or) pH > 3.6, because of present chelate.
- IMPORTANT: Acids destroy chelates.

**Use Ammonium (NH₄⁺) to lower the pH in the root medium**
- Process: Plant physiological acidifying, reaction in 3 - 5 days, but steady;
- Products: ammonium containing products;
- Dosage depends on the pH and product specification;
- Dosage in A tank or B tank, depending of the product.
Use of acid to correct pH water.

Neutralize bicarbonate (minus 0.5 - 0.9 mmol/l) in B tank with:
• concentrated Nitric acid.

Fine tuning of pH drip water in Acid/Hydroxide tank (Z/L) with:
• or diluted nitric acid (pH ↓)
• or diluted bicarbonate solution (pH ↑)
Use of acids in stock solution

Example:
HCO₃⁻ in water: 2,5 mmol/l ( = 152,5 ppm)
To neutralize: 2,5 – 0,5 = 2,0 mmol/l H⁺ needed.

Tank size: 1000 liter
Stock solution: 100x concentrated
Total water: 1000 x 100 = 100 000 liter
Total H⁺ needed: 100 000 l x 2,0 mmol/l = 200 000 mmol H⁺ = 200 mol H⁺

Specification acid: Nitric acid 38%: 6,0 mol H/kg
Density: 1,24 kg/l

Needed: 200 mol H⁺
6 mol H⁺/kg = 33,3 kg = 26,9 liter in B tank
Think about the present of chelates in the same tank!
Use of acids for pH↓ fine tuning

Via pH control unit on fertiliser unit (Z/L tank).
Separate injection pump connected to pH measurement.
Diluted nitric acid in “Z/L” tank.
To neutralize the last part of bicarbonate and to obtain the right drip water pH.

**General Guidelines:**
Switch fertiliser unit to acidify mode.
Start with Z/L tank filled for 50% with rainwater.
Prepare a 5 – 10% nitric acid solution in this tank:
- to strong: dilute with rainwater.
- to weak add nitric acid.

Optimal concentration of acid depends on: injection pump, system, acid specification, water.
The injection pump need to run in a nice rhythm and the pH should be steady.
pH control is: Trial and Error method.
Use of bicarbonate for pH↑ fine tuning

Via pH control unit on fertiliser unit (Z/L tank)
Separate injection pump connected to pH measurement
Diluted bicarbonate in “Z/L” tank.
To raise the pH to obtain the right drip water pH

General Guidelines:
Switch fertiliser unit to alkaline mode.
Start with Z/L tank filled for 50% with rainwater (without Ca, P).
Prepare a 5 – 10% potassium bicarbonate solution:
  - to strong: dilute with rainwater.
  - to weak add potassium bicarbonate .

Optimal concentration of bicarbonate depends on: injection pump, system, product specification, water. The injection pump need to run in a nice rhythm and the pH should be steady. pH control is: Trial and Error method.
The effect of N source on the soil pH

The pH of the soil with Calcium nitrate was higher than with ammonium sulfate (2 year)

(source: Zazoski, 1994)
Effect of NH$_4^+$ leakage in hydroponic

No or less NH$_4^+$ is left in the nutrient solution;
- Common practice at the start: Extra dosage of Calcium and Phosphorus;
- pH will increase during strong vegetative growth (and NO$_3^-$ uptake);
- pH > 6.2 in root medium: phosphorus precipitation;
- pH > 7.0 is not an exception at strong vegetative growth!

- CaHPO$_4$ precipitation when: P > 1.8 mmol/l, pH > 6.2 and Ca presence.

- pH > 7.0 then less available: P, Mn, Zn, Cu and Fe (depending of chelate)

A small dosage of Ammonium is essential for an optimal pH and nutrient availability in the root medium!
Too much ammonium results in too low pH!!
Ammonium dosage

- Check pH and EC every day
  - root medium
  - drain water

- Adapt the Ammonium concentration

- Take actions in advance

- Ammonium dosage - a fine-tune action
pH Correction in hydroponic

Table is based on analyses results of the water in the root medium.

<table>
<thead>
<tr>
<th>NH$_4^+$ mmol/l</th>
<th>HCO$_3^-$ mmol/l</th>
<th>&lt;5.0</th>
<th>5.0 - 5.5</th>
<th>5.5 - 6.0</th>
<th>6.0 - 6.5</th>
<th>6.5 - 7.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.5</td>
<td>&lt; 0.5</td>
<td>1</td>
<td>ok</td>
<td>ok</td>
<td>ok</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>0.5 - 1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt; 1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.5 - 1.0</td>
<td>&lt; 0.5</td>
<td>1</td>
<td>ok</td>
<td>ok</td>
<td>ok</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>0.5 - 1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt; 1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0 - 1.5</td>
<td>&lt; 0.5</td>
<td>1</td>
<td>1</td>
<td>ok</td>
<td>ok</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>0.5 - 1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt; 1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.5 - 2.0</td>
<td>&lt; 0.5</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>0.5 - 1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt; 1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: WUR/PPO The Netherlands

1. Increase the pH of the drip water (not above pH 6,2). Don’t use Ammonium nitrate.
2. Decrease the pH of the drip water (not below pH 5,0).
3. Expectation: pH will decrease automatically, because of high concentration on NH$_4^+$.
4. Don’t use extra Ammonium nitrate. Decrease the pH of the drip water (not below pH 5.0).
5. Expectation: pH will decrease further. Take all the Ammonium nitrate out the nutrient solution.
6. Decrease the pH of the drip water (not below pH 5.0), increase NH$_4^+$ concentration a little bit (0.0 0.2 – 0.4 mmol/l *).
7. Decrease the pH of the drip water (not below pH 5.0), increase NH$_4^+$ concentration a little bit more (0.4 – 0.6 mmol/l *).
8. Decrease the pH of the drip water (not below pH 5.0), increase NH$_4^+$ concentration (0.4 – 0.8 mmol/l *).

*) Exact dosage of NH$_4^+$ is depends on the crop, see book: “Bemestingsadviesbasis Substraten”.
Examples of extra ammonium nitrate (no recirculation system).

<table>
<thead>
<tr>
<th>Tomato (rock wool)</th>
<th>Sweet pepper (rock wool)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Combination class</strong></td>
<td><strong>Combination class</strong></td>
</tr>
<tr>
<td>(see table)</td>
<td>(see table)</td>
</tr>
<tr>
<td>Extra mmol</td>
<td>Extra mmol</td>
</tr>
<tr>
<td>ammonium nitrate/l</td>
<td>ammonium nitrate/l</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>+ 0,4</td>
<td>+ 0,0</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>+ 0,6</td>
<td>+ 0,3</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>+ 0,8</td>
<td>+ 0,5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cucumber (rock wool)</th>
<th>Cucumber (coco substrate)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Combination class</strong></td>
<td><strong>Combination class</strong></td>
</tr>
<tr>
<td>(see table)</td>
<td>(see table)</td>
</tr>
<tr>
<td>Extra mmol</td>
<td>Extra mmol</td>
</tr>
<tr>
<td>ammonium nitrate/l</td>
<td>ammonium nitrate/l</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>+ 0,4</td>
<td>+ 0,2</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>+ 0,6</td>
<td>+ 0,4</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>+ 0,8</td>
<td>+ 0,6</td>
</tr>
</tbody>
</table>

Source: WUR/PPO The Netherlands
Plant physiological conversion of Ammonium

- Uptake of NH$_4^+$ cause acidification of rhizosphere.
- 3 theories, same result:

Theory 1: Ion exchange.

Theory 2: NH$_3$ intern transport

Theory 3: NH$_2$ intern transport

\[
pH = -\log [H^+]
\]

High concentration H$^+$: lower pH
pH and urea

1. $\text{CO(NH}_2\text{)}_2 + \text{H}_2\text{O} \ ( + \text{enzyme: urease}) \rightarrow 2\text{NH}_3 \ + \text{CO}_2$
2. $2\text{NH}_3 \ + 2\text{H}_2\text{O} \rightarrow 2\text{NH}_4^+ \ + 2\text{OH}^- \ (\text{pH} \uparrow \text{ and EC} \uparrow)$
3. $2\text{NH}_4^+ \ + 3\text{O}_2 \ ( + \text{bacterial action}) \rightarrow 2\text{NO}_2^- \ + 4\text{H}^+ \ + 2\text{H}_2\text{O} \ (\text{pH} \downarrow \downarrow)$
4. $2\text{NO}_2^- \ + \text{O}_2 \ ( + \text{bacterial action}) \rightarrow 2\text{NO}_3^-$

**Summary:** $\text{CO(NH}_2\text{)}_2 + 4\text{O}_2 \ ( + \text{bacteria/enzyme}) \rightarrow 2\text{NO}_3^- + 2\text{H}^+ + \text{CO}_2 + \text{H}_2\text{O} \ (\text{pH} \downarrow \text{ and EC} \uparrow)$

**Step 1 – 2 takes:**
- $2^\circ\text{C} \rightarrow 4 \text{ days}$
- $10^\circ\text{C} \rightarrow 2 \text{ days}$
- $20^\circ\text{C} \rightarrow 1 \text{ day}$

**Step 3 – 4 takes:**
- $5^\circ\text{C} \rightarrow 6 \text{ weeks}$
- $8^\circ\text{C} \rightarrow 4 \text{ weeks}$
- $10^\circ\text{C} \rightarrow 2 \text{ weeks}$
- $20^\circ\text{C} \rightarrow 1 \text{ week}$

Urea = $\text{CO(NH}_2\text{)}_2$
Urea and pH

Urea $\rightarrow$ $2 \text{NH}_4^+ + 2 \text{OH}^-$

($=\text{increase of soil pH}$)

$2 \text{NH}_4^+ \rightarrow \text{Nitrate} + 4 \text{H}^+$

($=\text{decrease soil pH}$)

Original soil pH before Urea application

Soil pH

Raise

Lowering

Weeks after urea application

Source: Linser, 1972
pH and urea

Change of Urea strongly depends on: temperature, moist and oxygen contents, presence of bacteria and enzymes.

- First pH increase due to formation of OH⁻ followed by pH drop (increase of H⁺).
- NH₃ concentration (ammonia) is temporarily, may cause problems in O₂ poor environments and alkaline soils.
- NH₃ (ammonia) is toxic for plants.
- The EC of the solution is higher after the breakdown of the urea.
- The breakdown speed is not stable.
- **Urea never to be used in substrate cultures,** due to pH root sensitivity (limited root volume, soil buffering effect not present.)
- Dosing by means of EC levels is not possible.
- Fertigation is a controllable method, Urea cannot be measured and is not suitable here.
Safety
Handling of acids.

CLEARLY LABEL WHERE ACIDS ARE STORED

ALWAYS WEAR SUITABLE PROTECTIVE CLOTHING AND GLOVES WHEN USING ACIDS

Wear face shield

Wear protective clothing
Handling of acids.

**Always** add acid to water, **never** water to acid.

Example
Density acid: 1,3 kg/l

Density water: 1,0 kg/l

And...
don’t forget to wear protective clothing and gloves.

 Wear face shield

 Wear protective clothing
Dangerous combinations

Acid + Base

- Nitric acid + a (bi)carbonate
  - Explosive CO$_2$ reaction + heat
  - Tank can explode

- Nitric acid + a hydroxide
  - Violent reaction with heat development
  - Tank can melt away

- Hydroxide is more dangerous than acid
  - Difficult too remove
  - It don’t burn on your skin, too late warning!
In case of an emergency:

1. Don’t panic,
2. Remove clothing,
3. Prolonged rinsing with a lot of water,
4. Consult a doctor immediately,
   Take the MSDS and/or the label with you to the doctor.
Tomato
Fertiliser recipe: Tomato in greenhouse soil

Base dressing needed. Amount and type of fertilisers are based on soil analysis.

Standard nutrient solution for fertigation in greenhouse soil:

<table>
<thead>
<tr>
<th>Fertigation</th>
<th>N-NH₄</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>N-NO₃</th>
<th>S</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>mmol/l</td>
<td>0,4</td>
<td>5,0</td>
<td>2,0</td>
<td>1,5</td>
<td>9,4</td>
<td>1,5</td>
<td></td>
</tr>
<tr>
<td>mg/l</td>
<td>6</td>
<td>196</td>
<td>80</td>
<td>36</td>
<td>132</td>
<td>48</td>
<td></td>
</tr>
</tbody>
</table>

Standard N dosage: 7 mmol/l

Source: WUR/PPO The Netherlands

Standard nutrient solution must be adapted according to soil analysis, to correct the ratio between nutrients in the soil.

Take a water sample and take the nutrient content of the water into account.
General example Kristalon: Tomato standard fertiliser recipe in greenhouse soil

<table>
<thead>
<tr>
<th>Growth medium: Soil</th>
<th>Macro nutrients concentration in mmol/l</th>
<th>Micro nutrients concentration in µmol/l</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NH&lt;sub&gt;4&lt;/sub&gt;&lt;sup&gt;+&lt;/sup&gt; K&lt;sup&gt;+&lt;/sup&gt; Ca&lt;sup&gt;2+&lt;/sup&gt; Mg&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>Fe Mn Zn B Cu Mo</td>
</tr>
<tr>
<td>Standard nutrient solution</td>
<td>0,40 5,00 2,00 1,50</td>
<td>9,40 1,50</td>
</tr>
<tr>
<td>Result of fertiliser mix</td>
<td>0,52 4,99 2,59 1,45</td>
<td>9,20 1,53 1,10</td>
</tr>
</tbody>
</table>

Standard N dosage: 7 mmol/l

**Other A tank options:**
- Krista Mag
- Krista K
- Yara Rexolin micro nutrients

**Other B tank options** in combination with Calcinit (A tank):
- Kristalon Brown
- Kristalon Orange
- Kristalon Red

A recommendation based on your local conditions could be made. Ask your Yara dealer. Concentration (EC) dripwater depends on Nitrogen in soil analysis and period of the year.
Fertiliser recipe: Tomato in Rock wool

Standard nutrient solution (Rock wool)

<table>
<thead>
<tr>
<th>N-NH₄</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>N-NO₃</th>
<th>S</th>
<th>P</th>
<th>Fe</th>
<th>Mn</th>
<th>Zn</th>
<th>B</th>
<th>Cu</th>
<th>Mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>mmol/l</td>
<td>1,2</td>
<td>9,5</td>
<td>5,4</td>
<td>2,4</td>
<td>16</td>
<td>4,4</td>
<td>1,5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mg/l</td>
<td>17</td>
<td>371</td>
<td>217</td>
<td>58</td>
<td>224</td>
<td>141</td>
<td>47</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>µmol/l</td>
<td>15</td>
<td>10</td>
<td>5</td>
<td>30</td>
<td>0,75</td>
<td>0,5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>mg/l</td>
<td>0,84</td>
<td>0,55</td>
<td>0,33</td>
<td>0,32</td>
<td>0,05</td>
<td>0,05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: WUR/PPO The Netherlands

Standard nutrient solution must be adapted according substrate analysis, to correct the ratio between nutrients in the substrate.

Take a water sample and take the nutrient content of the water into account. Measure pH and EC of the substrate everyday.
## Corrections for crop stages Tomato rock wool

<table>
<thead>
<tr>
<th>Growth stage</th>
<th>NO$_3$</th>
<th>S</th>
<th>P</th>
<th>NH$_4$</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>B (umol/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filling new Rockwool</td>
<td>+ 0,25</td>
<td>- 0,5</td>
<td>- 1,2</td>
<td>- 3,8</td>
<td>+ 1,5</td>
<td>+ 1,0</td>
<td>+ 10</td>
<td></td>
</tr>
<tr>
<td>Start till start flower 3th cluster</td>
<td>+ 1,0</td>
<td></td>
<td></td>
<td>- 1,0</td>
<td>+ 0,5</td>
<td>+ 0,5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard recipe</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From start flowering 3th cluster</td>
<td>+ 0,5</td>
<td>- 0,125</td>
<td>- 0,125</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From start flowering 5th cluster</td>
<td>+ 1,75</td>
<td>- 0,625</td>
<td>- 0,25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From start flowering 10th cluster</td>
<td>+ 0,5</td>
<td>- 0,125</td>
<td>- 0,125</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From start flowering 12th cluster</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: WUR/PPO The Netherlands
**General example Kristalon:**
**Tomato standard fertiliser recipe in Rock wool**

<table>
<thead>
<tr>
<th>Growth medium: Rockwool</th>
<th>Macro nutrients concentration in mmol/l</th>
<th>Micro nutrients concentration in µmol/l</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N-NH₄⁺</td>
<td>K⁺</td>
</tr>
<tr>
<td>Standard nutrient solution</td>
<td>1,20</td>
<td>9,50</td>
</tr>
<tr>
<td>Result of fertiliser mix</td>
<td>1,08</td>
<td>9,49</td>
</tr>
</tbody>
</table>

**Other A tank options:**
- Krista Mag
- Krista K
- Yara Rexolin micro nutrients

**Other B tank options** in combination with Calcinit in A tank:
- Kristalon Brown
- Kristalon Orange

A recommendation based on your local conditions could be made. Ask your Yara dealer.
EC drip water depends on local conditions.
Stage 1 - Focus on growth
from start to flowering cluster 2 – 3
- 1,20 g/l FERTICARE TOMATO
- 1,41 g/l; YaraLiva CALCINIT

Stage 2 – Balanced growth / generative
flowering clusters 3 – 6
- 1,15 g/l FERTICARE TOMATO
- 1,36 g/l YaraLiva CALCINIT
- 0,19 g/l KRISTA K

Stage 3 - Strong generative focus
until first harvest
- 1,20 g/l FERTICARE TOMATO
- 1,22 g/l YaraLiva CALCINIT
- 0,24 g/l KRISTA K

Stage 4 - Re-growth (=Stage 2)

The above recommendations are made for 100% clean rainwater to reach EC 2,7
A recommendation based on your local conditions could be made. Ask your Yara dealer.
Special attentions in tomato nutrition hydroponics

Nitrogen essential for growth
- Too much NO$_3$ leads to
  - A strong vegetative growth
  - Less flowers, slow fruit set and ripening
  - Extra sensitivity for diseases
  - Puffiness

Ammonium essential for pH
- Too much NH$_4$ will restrict Ca-uptake, and risks burning root tips (acidity)
- A low NH$_4$ risks a high pH:
  - Risk of Ca, P, Fe precipitation.
  - Clogged drippers
Special attention in tomato nutrition in hydroponics

Phosphorus essential for roots / fruits
• Too much P risks precipitation, and clogged drippers
• A high pH risks P – deficiency, followed by precipitation / clogged drippers

Potassium essential for fruits
• High K is needed:
  • Improve uniformity of ripening & shape
  • For fruit quality / aroma / brix
  • To Avoid puffiness
• Too much K will restrict Ca-uptake
Special attention in tomato nutrition hydroponics

**Magnesium for color / chlorophyll**
- Too much Mg will restrict Ca- and / or K-uptake
- (Too) high K risks a Mg-deficiency
  Mainly show up at heavy fruit load period
  Visible in the oldest leaves

**Iron essential for color / chlorophyll**
- A high pH risks Fe-deficiency
  At the top, in youngest leaves
Special attention in tomato nutrition hydroponics

**Calcium essential for cell strength**
- Uptake process is difficult, fully linked to water uptake
- Redistribution of calcium in the plant does not happen
- Ca - deficiency mainly caused by
  - Climate / low evaporation / water-uptake
  - Too much K, NH4, Mg
- Results in Blossom end rot (BER)
Calcium uptake is mainly driven by evaporation.

Calculated uptake is pulled up by the transpiration stream via xylem vessels.

Accumulation in the transpiring tissues, e.g., leaves, are poor in Calcium.

Organs of low transpiration, are poor in Calcium.

Calcium is pulled up by the transpiration stream via xylem vessels.
Calcium uptake during growth

Ca$^{2+}$ uptake: Passive process

Vegetative growth
- Root growth
- Calcium uptake

Generative growth
- No root growth
- No Calcium uptake
How you can help Calcium ....

• Take care about young / fresh root tips.
• Potassium not too high.
• Magnesium not too high.
• $\text{NH}_4^+$ not too high.
• Stimulates the evaporation for better Calcium uptake.
• Take care about available Calcium (Use Calcinit)
• Keep Calcium available by pH control.

Use always a balanced nutrient solution!!

Antagonism with Calcium.
Special attention in tomato nutrition hydroponics

Tomatoes in rock wool like optional Chloride.

Benefits of Chloride
- Improves the taste of fruit
- Chloride increases Calcium-uptake

Dosage
- 2.25 mmol Cl ( = 80 mg/l)
- Cl input is compensated by lower NO$_3^-$
Cucumber
Fertiliser recipe: Cucumber in greenhouse soil

Base dressing needed. Amount and type of fertilisers are based on soil analysis.

Standard nutrient solution for fertigation in greenhouse soil:

<table>
<thead>
<tr>
<th>Standard nutrient solution (soil fertigation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertilization</td>
</tr>
<tr>
<td>mmol/l</td>
</tr>
<tr>
<td>mg/l</td>
</tr>
</tbody>
</table>

Standard N dosage: 7 mmol/l

Standard nutrient solution must be adapted according to soil analysis to correct the ratio between nutrients in the soil.

Take a water sample and take the nutrient content of the water into account.
General example Kristalon: Cucumber fertiliser recipe in greenhouse soil

<table>
<thead>
<tr>
<th>Growth medium: Soil</th>
<th>Macro nutrients concentration in mmol/l</th>
<th>Micro nutrients concentration in µmol/l</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N-NH₄⁺  K⁺  Ca²⁺  Mg²⁺</td>
<td>N-NO₃⁻  Cl⁻  SO₄²⁻  H₂PO₄⁻</td>
</tr>
<tr>
<td>Standard nutrient solution</td>
<td>0,90  3,50  2,00  1,00</td>
<td>8,40  1,00</td>
</tr>
<tr>
<td>Result of fertiliser mix</td>
<td>0,55  3,50  2,72  0,96</td>
<td>8,44  1,02  0,77</td>
</tr>
</tbody>
</table>

Standard N dosage: 7 mmol/l

A recommendation based on your local conditions could be made. Ask your Yara dealer. Concentration (EC) dripwater depends of Nitrogen in soil analysis and period of the year.

Other A tank options:
• Krista K
• Krista MAG
• Rexolin micro nutrients

Other B tank options in combination with Calcinit (A tank):
• Kristalon Scarlet
• Kristalon Orange
• Kristalon Red
• Ferticare Hydro
Fertiliser recipe: Cucumber in Rock wool

Standard nutrient solution (Rock wool)

<table>
<thead>
<tr>
<th></th>
<th>N-NH₄</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>N-NO₃</th>
<th>S</th>
<th>P</th>
<th>Fe</th>
<th>Mn</th>
<th>Zn</th>
<th>B</th>
<th>Cu</th>
<th>Mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>mmol/l</td>
<td>1,25</td>
<td>8,0</td>
<td>4,0</td>
<td>1,375</td>
<td>16,0</td>
<td>1,375</td>
<td>1,25</td>
<td>15</td>
<td>10</td>
<td>5</td>
<td>25</td>
<td>0,75</td>
<td>0,5</td>
</tr>
<tr>
<td>mg/l</td>
<td>18</td>
<td>313</td>
<td>160</td>
<td>33</td>
<td>224</td>
<td>44</td>
<td>39</td>
<td>0,84</td>
<td>0,55</td>
<td>0,33</td>
<td>0,27</td>
<td>0,05</td>
<td>0,05</td>
</tr>
</tbody>
</table>

Standard nutrient solution must be adapted according substrate analysis, to correct the ratio between nutrients in the substrate.

Take a water sample and take the nutrient content of the water into account.

Measure pH and EC of the substrate everyday.
# Corrections for crop stages Cucumber rock wool

<table>
<thead>
<tr>
<th>Growth stage</th>
<th>NO$_3$</th>
<th>S</th>
<th>P</th>
<th>NH$_4$</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>B (umol/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filling new Rockwool</td>
<td></td>
<td></td>
<td></td>
<td>- 0,4</td>
<td>- 2,5</td>
<td>+ 0,7</td>
<td>+ 0,75</td>
<td>+10</td>
</tr>
<tr>
<td>Start (first weeks)</td>
<td></td>
<td></td>
<td></td>
<td>- 1,0</td>
<td>+ 0,5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy fruit load</td>
<td>+ 1,0</td>
<td></td>
<td></td>
<td></td>
<td>+ 1,0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: WUR/PPO The Netherlands
## General example Kristalon: Cucumber standard fertiliser recipe in Rock wool

<table>
<thead>
<tr>
<th>Growth medium:</th>
<th>Macro nutrients concentration in mmol/l</th>
<th>Micro nutrients concentration in µmol/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rockwool</td>
<td>N-NH₄⁺  K⁺  Ca²⁺  Mg²⁺</td>
<td>N-NO₃⁻  Cl⁻  SO₄²⁻  H₂PO₄⁻</td>
</tr>
<tr>
<td>Standard nutrient solution</td>
<td>1,25  8,00  4,00  1,38</td>
<td>16,00  1,38  1,25</td>
</tr>
<tr>
<td>Result of fertiliser mix</td>
<td>0,88  7,99  4,38  1,61</td>
<td>16,12  1,31  1,76</td>
</tr>
</tbody>
</table>

**Other A tank options:**
- Krista K
- Krista MAG
- Rexolin micro nutrients

**Other B tank options** in combination with Calcinit (A tank):
- Kristalon Brown
- Kristalon Orange

A recommendation based on your local conditions could be made. Ask your Yara dealer.

EC drip water depends on local conditions.
FERTICARE VEGETABLES for Cucumber  
crop specific water soluble NPK solutions

Stage 1 - Focus on growth
The first 3 weeks
- 0.95 g/l FERTICARE VEGETABLES
- 1.10 g/l YaraLiva CALCINIT
- 0.18 g/l KRISTA K

Stage 2 – Balanced growth / generative
From week 3 until to first harvest
- 0.94 g/l FERTICARE VEGETABLES
- 0.98 g/l YaraLiva CALCINIT
- 0.29 g/l KRISTA K

Stage 3 - Heavy fruit load
Strong generative focus
- 0.88 g/l FERTICARE VEGETABLES
- 0.94 g/l YaraLiva CALCINIT
- 0.41 g/l KRISTA K

The above recommendations are made for 100% clean rainwater to reach EC 2.2
A recommendation based on your local conditions could be made. Ask your Yara dealer.
Special nutriënt needs Cucumber

Cucumber in Rock wool needs optional Silicium (Si).

Benefits: To improve the quality and yield of the fruit. Silicium makes the plant better resistant against Powdery Mildew.

Dosage: 0.75 mmol Si/l ( = 21 mg/l) by potassium meta silicate (Yara Sikal) in a diluted nutrient solution.
Finally
Interested in the full fertiliser story and all details?

New Fertilization book available via Amazon.com

ISBN 13: 9789048125319
ISBN 10: 9048125316
Yara has a full portfolio of fertigation fertilisers

**Yara Liva Calcinit**

**Krista range:** Straight ws-fertilisers

**Water Soluble NPK:** e.g. Kristalon.

**Yara Vita Rexolin:**
Chelated micro nutrients
Thank you for your attention!

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