Knowledge grows

Workshop fertigation in horticultural crops

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Knowledge grows

Basics of fertigation

Part 1

Soil cultivation versus substrate

		Soil	substrate
1.	Root volume:	> 500 l/m^2	< 15 l/m^2
2.	Nutrient storage & stock:	> 50% (tomato)	< 5% (tomato)
3.	Micro nutrients:	often present	needed
4.	Buffering capacity (CEC):	often present	does not occur
5.	pH:	depends on soil	depends on grower
6.	Ammonium (NH_4^+):	depends on soil	**Highly** sensitive
7.	Urea:	allowed	**Not** allowed
8.	Salination:	less sensitive	Highly sensitive
9.	Water quality	important	extreme important
10.	Calcium (Ca^2	Often beneficial	Absolutely needed!

Water quality

Water quality for horticultural use

		Standard 1	Standard 2	Standard 3	Standard 4
EC	in mS/cm	< 0.5	< 1.0	< 1.5	> 1.5
Na^+	in mmol/l (mg/l)	< 1.5 (<35)	< 3.0 (<69)	< 4.5 (<104)	> 4.5 (>104)
Cl^-	in mmol/l (mg/l)	< 1.5 (<53)	< 3.0 (<106)	< 4.5 (<160)	> 4.5 (>160)

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

Crop	Max. Na (mmol/l)
Tomato	8
Sweet pepper, Egg plant	6
Cucumber, Melon	6
Rose, Gerbera	4
Anthurium, Bouvardia, Lilium	3

Source: WUR/PPO The Netherlands

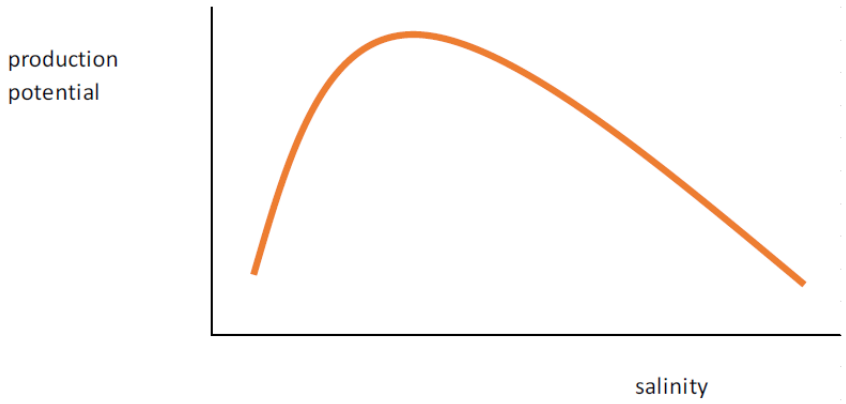


Figure salinity: free according Sonneveld (1991).

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.

Crop	max. Na (mmol/l)	max. Cl (mmol/l)
Rose	0,2	0,3
Sweet pepper, Egg plant	0,2	0,4
Anthurium, Bean	0,3	0,5
Gerbera	0,4	0,6
Cucumber, Melon	0,5	0,7
Tomato	0,7	0,9

Source: WUR/PPO The Netherlands

Hard water it self, is not a problem: use acid.

- HCO_3 250 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 + HCO_3 + H^+ + NO_3

→ Ca + Mg + CO_2 + H_2O + NO_3

→ Ca + Mg + NO_3

Hard water contains nutrients for free!

Bicarbonate must be neutralized with acid.

			BEVATTNING
pH			7.30
Ledningstal	mS/cm		0.500
Nitratkväve	mg/l		1.36
Fosfor	mg/l		1.81
Kalium	mg/l		11.2
Magnesium	mg/l		9.19
Svavel	mg/l		14.1
Kalcium	mg/l		87.4
Natrium	mg/l		14.5
Klorid	mg/l		15.7
Mangan	mg/l		0.030
Bor	mg/l		0.033
Koppar	mg/l		0.024
Järn	mg/l		0.166
Zink	mg/l		0.033
Molybden	mg/l		0.008
Aluminium	mg/l		0.032
Kisel	mg/l		2.64
Ammoniumkväve	mg/l	<	0.100
Alkalinitet	mg/l		250

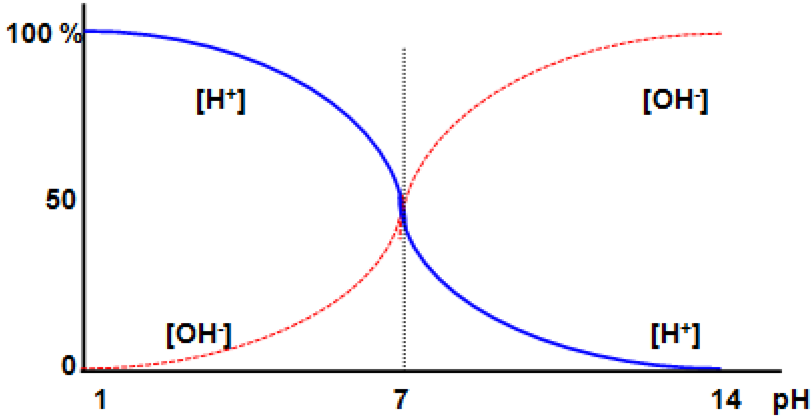
pH: power or potenz of hydrogen

- **pH** is measure the acidity of a solution in terms of activity of hydrogen (H^+).
- The pH scale is a **reverse logarithmic** representation of H^+ concentration.
- **Definition:** pH = - log [H^+].
- **pH** is a scale of acidity from 0 to 14.

Acid: pH 1 = 1×10^{-1} = 0,1 mol H^+ / l.

Alkaline: pH 14 = 1×10^{-14} = 0, 00 000 000 000 001 mol H^+ / l

$log_{10}(x)$	value
-7	0,0000001
-6	0,000001
-5	0,00001
-4	0,0001
-3	0,001
-2	0,01
-1	0,1
0	1
1	10
2	100
3	1000
4	10000
5	100000
6	1000000
7	10000000



pH and (bi)carbonate

How much acid is needed to correct the pH?

Calculation of the amount of acid to change the pH from pH 7 to pH 5
in a solution **without** bi carbonate:

pH 5 = 1×10^{-5} = 0,00 001 mol H^+/l
pH 7 = - 1×10^{-7} = 0,0 000 001 mol H^+/l
$9{,}9 \times 10^{-6}$ = 0,0 000 099 mol H^+/l for pH correction

Nitric acid 62% contains 9,84 mol H^+ / kg

Needed: $9{,}9 \times 10^{-6}$ mol H^+/ l .
9,84 mol H^+/kg = 1×10^{-6} kg = 1 mg Nitric acid / litre water

pH and (bi)carbonate

How much acid is needed to correct the pH in moderate hard water?

Calculation of the amount of acid to change the pH from pH 7 to pH 5 in a solution with 1 mmol bicarbonate /l (= 61 ppm):

pH 5 = 1×10^{-5} = 0,00 001 mol H^+/l

pH 7 = - 1×10^{-7} = 0,0 000 001 mol H^+/l

$9,9 \times 10^{-6}$ = 0,0 000 099 mol H^+/l for pH correction

\+ 1×10^{-3} = 0,001 mol H^+/l for neutralizing the bicarbonate

$1,01 \times 10^{-3}$ = 0,0 010 099 mol H^+/l total

Nitric acid 62% contains 9,84 mol H^+ / kg

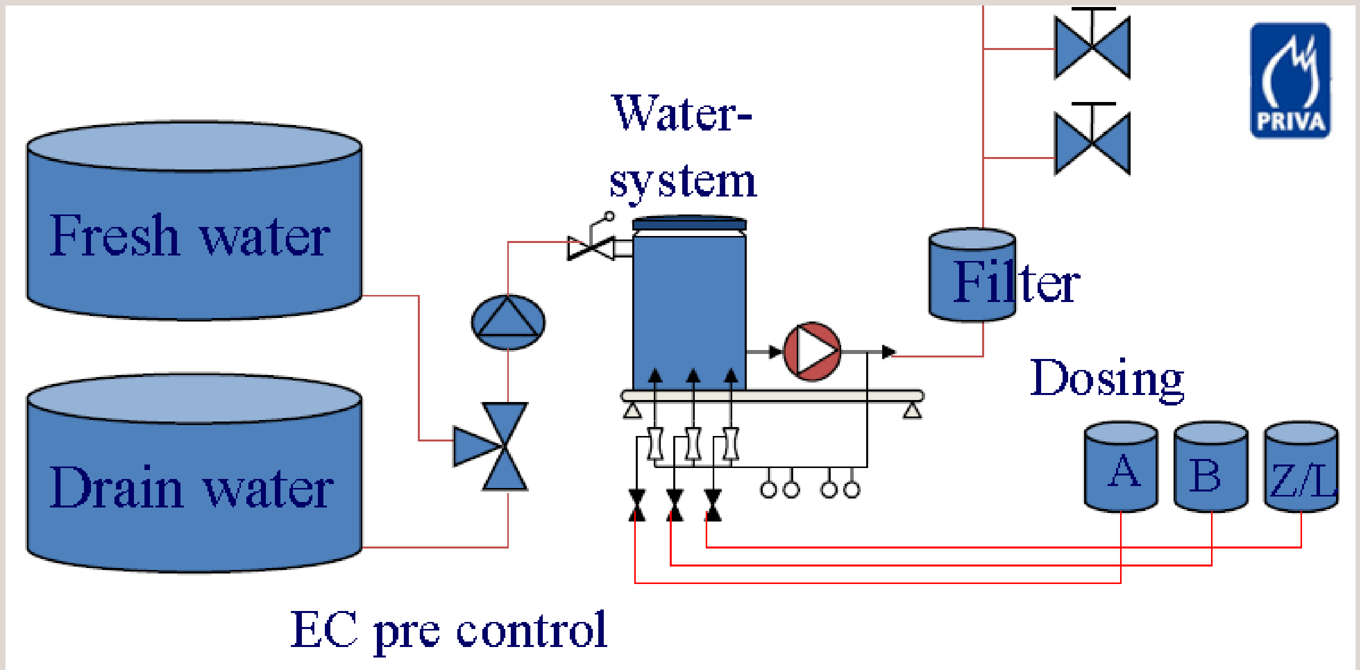
Needed: $\frac{1,01 \times 10^{-3} \text{ mol } H^+/\text{l}}{9,84 \text{ mol } H^+/\text{kg}}$ = $1,02 \times 10^{-4}$ kg = 102 mg Nitric acid / litre water

= > 100 x more!

This is not only theory:

Neutralize main part of bicarbonate (minus 0,5 – 0,9 mmol / l) in **B tank** with:
• concentrated Nitric acid.

Neutralizing of last part bicarbonate and fine tuning of pH drip water in Acid / Hydroxide **tank (Z/L)** with:
• diluted nitric acid (pH ↓)
• diluted bicarbonate solution (pH ↑)



pH and (bi)carbonate

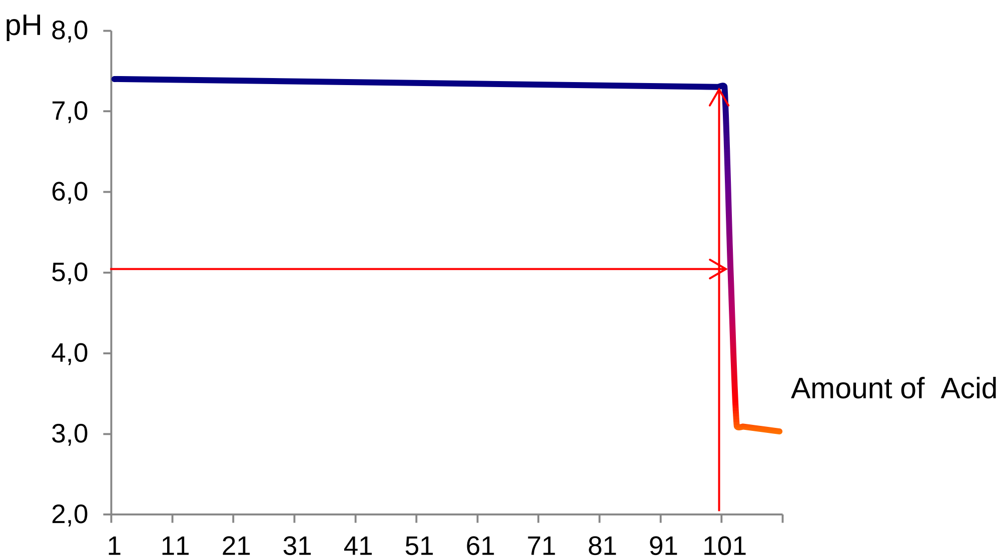
Due to the logarithmic scale of pH, it's not possible:

- to calculate exact the right amount of acid, to change the pH.

- to dose the exact amount acid is in practical conditions too.

<u>That's why we leave 0,5 - 0,9 mmol HCO_3 /l in the water,</u>

<u>and let the fertilizer unit fine-tune the pH with diluted acid.</u>



Main part of acid is needed for neutralizing bicarbonate.
The last drop changes the pH fast.

So…Stay away from the edge!

How to lower the pH ?

Use acids (H^+) to lower the pH of the water;

- Process: Chemical acidification, fast reaction:
  - $HCO_3^- + HNO_3 \longrightarrow H_2O + CO_2 \uparrow + NO_3^-$
- 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 chelate.
- IMPORTANT: Acids destroy chelates.

Use Ammonium (NH_4^+) 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 on the product.

Use of acids in stock solution

Example:

HCO_3^- in water: 2,5 mmol/l (= 152,5 ppm)

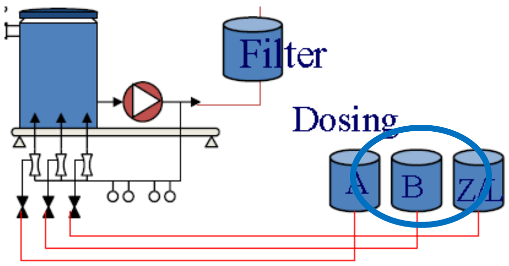
To neutralize: 2,5 – 0,5 = 2,0 mmol/l H^+ needed.

Tank size:	1000 liter
Stock solution:	100 x 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

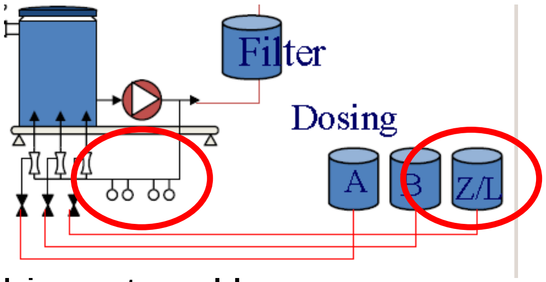
Needed: <u>200 mol H^+</u>

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:

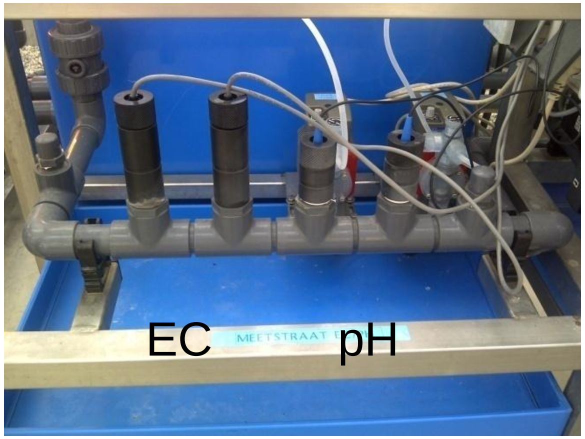
Switch fertilizer unit to acidify mode.

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 of: 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.

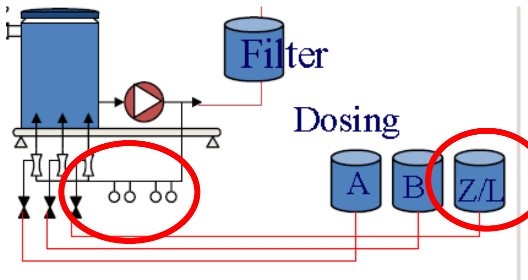
Use of bicarbonate for pH↑ fine tuning

Via pH control unit on fertiliser unit (Z/L tank).

Separate injection pump connected to pH measurement.

Diluted bicabonate in “Z/L” tank.

To raise the pH to obtain the right drip water pH.



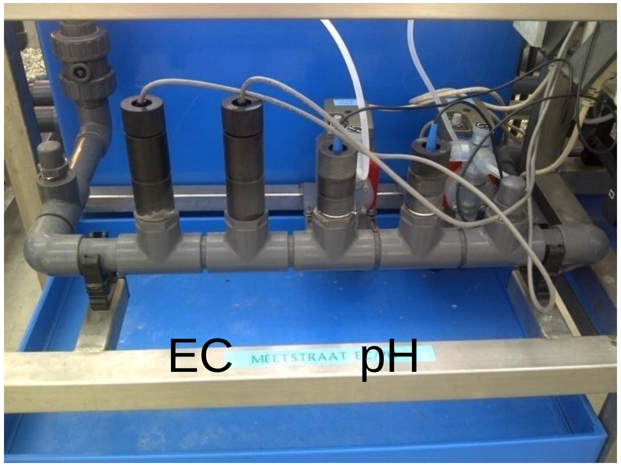
General Guidelines:

Switch fertilizer 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 (clean water)
- 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.

Chemical conversion of Ammonium

- Ammonium fertilizers (weak base):
  - Ammonium nitrate (solid or liquid): NH_4NO_3
  - Ammonium sulphate: $(NH_4)_2SO_4$
  - Mono ammonium phosphate: $NH_4(H_2PO_4)$

- Example:

$$NH_4NO_3 \rightarrow NH_4^+ + NO_3^-$$

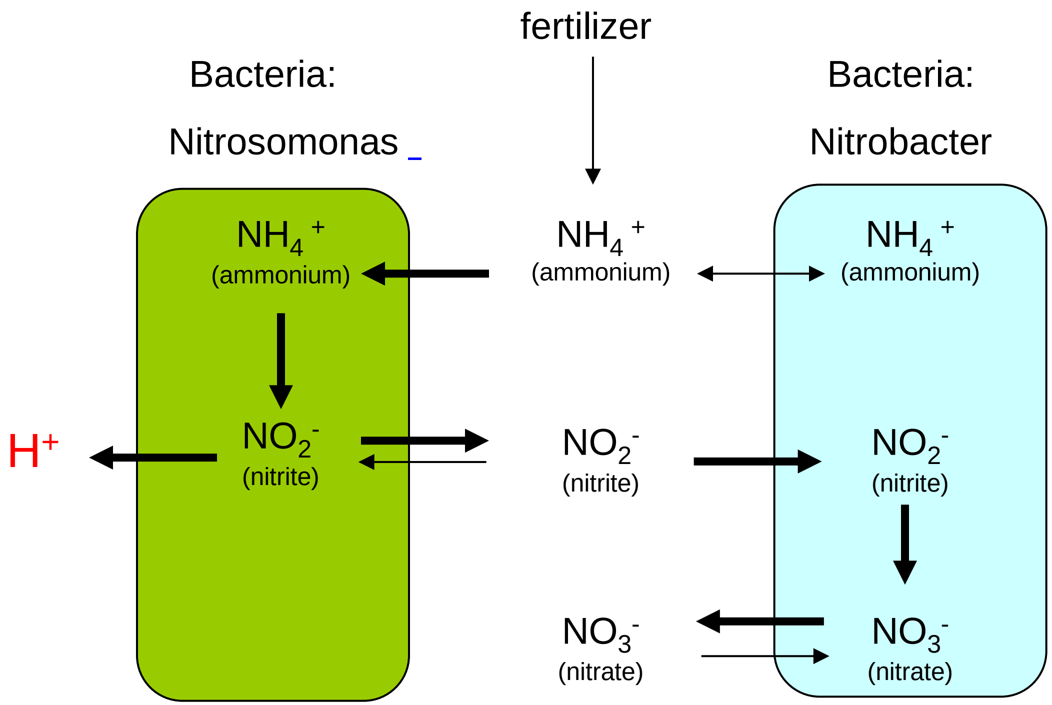
$$NH_4^+ + H_2O \rightarrow NH_3 + H^+ + H_2O$$

pH = - log [H^+]

Higher concentration H^+: lower pH

Bacteriological conversion of Ammonium

- $2NH_4^+ + 3O_2 \rightarrow 2NO_2^- + 4H^+ + 2H_2O$
- $2NO_2^- + O_2 \rightarrow 2NO_3^-$



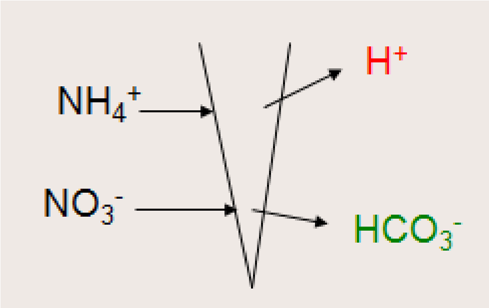
pH = - log [H+]

Higher concentration H+: lower pH

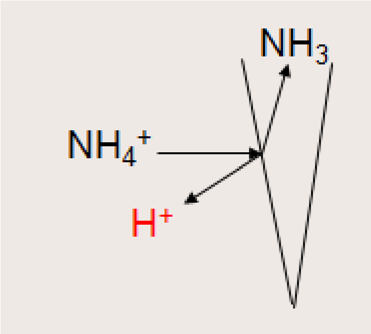
Plant physiological conversion of Ammonium

- Uptake of NH_4^+ cause acidification of rhizosphere.
- 3 theories, same result:

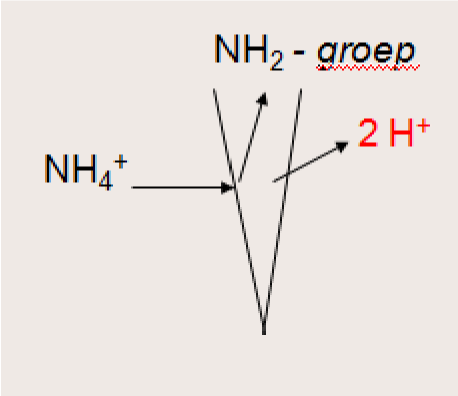
Theory 1:
Ion exchange.



Theory 2:
NH_3 intern transport



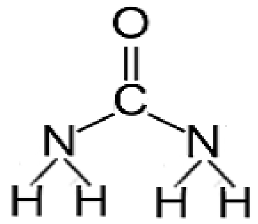
Theory 3:
NH_2 intern transport



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

Higher concentration H^+: lower pH

pH and urea ($CO(NH_2)_2$)



1. $CO(NH_2)_2 + H_2O$ (+ enzyme: urease) $\rightarrow 2NH_3 + CO_2$
2. $2NH_3 + 2H_2O \rightarrow 2NH_4^+ + 2OH^-$ (**pH** ↑ and **EC**↑)
3. $2NH_4^+ + 3O_2$ (+ bacterial action) $\rightarrow 2NO_2^- + 4H^+ + 2H_2O$ (**pH** ↓↓)
4. $2NO_2^- + O_2$ (+ bacterial action) $\rightarrow 2NO_3^-$

Summary: $CO(NH_2)_2 + 4O_2$ (+ bacteria / enzyme) $\rightarrow 2NO_3^- + 2H^+ + CO_2 + H_2O$
(**pH** ↓ and **EC**↑)

Step 1 – 2 takes:

2°C → 4 days
10°C → 2 days
20°C → 1 day

Step 3 – 4 takes:

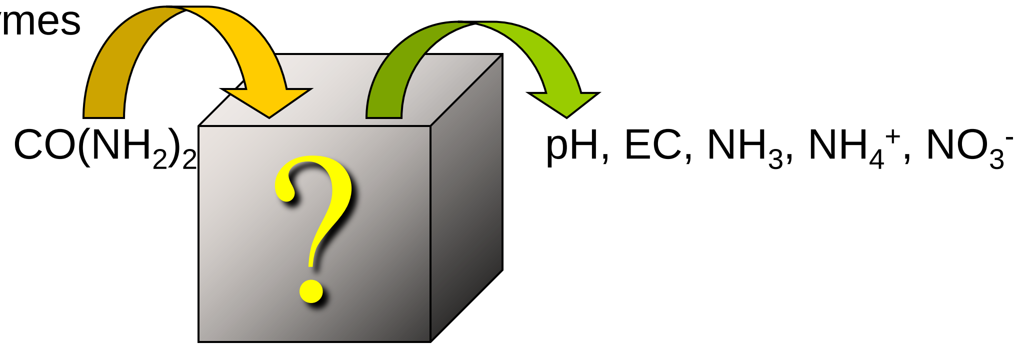
5°C → 6 weeks
8°C → 4 weeks
10°C → 2 weeks
20°C → 1 week

pH = - log [H^+]

Higher concentration H^+: lower pH

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^+)
- NH_3 concentration (ammonia) is temporarily, may cause problems in O_2 poor environments and alkaline soils.
- NH_3 (ammonia) is toxic for plants.
- The EC of the solution is higher after the breakdown of the urea.
- The breakdown speed is not stable.
- **<u>Urea never to be used in in substrate cultures</u>**, 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.

Ammonium dosage

- Check everyday the pH and EC of the root medium and drain water;
- Adapt the Ammonium concentration;
- Take actions in advance;
- The dosage of Ammonium is a fine-tuning action.

pH Correction in hydroponic

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

NH_4^+ mmol/l	HCO_3^- mmol/l	pH < 5.0	5.0 - 5.5	5.5 - 6.0	6.0 - 6.5	6.5 - 7.5
< 0.5	< 0.5	1	ok	ok	ok	6
	0.5 - 1.0			ok	6	7
	> 1.0				7	8
0.5 - 1.0	< 0.5	1	ok	ok 6	ok	6
	0.5 - 1.0			ok	ok	6
	> 1.0			ok	6	7
1.0 - 1.5	< 0.5	1	1	ok	ok	2
	0.5 - 1.0			ok	ok	6
	> 1.0			ok	2	6
1.5 - 2.0	< 0.5	5	5	3	3	4
	0.5 - 1.0			3	3	4
	> 1.0			3	4	4

Source: WUR/PPO The Netherlands

First step for Sweet pepper = +0

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".**

pH Correction in hydroponic

Examples of extra ammonium nitrate (no recirculation system).

Tomato (rock wool)

Combination class (see PPO book)	Extra mmol ammonium nitrate/l
6	+ 0,4
7	+ 0,6
8	+ 0,8

Rose (rock wool

Combination class (see PPO book)	Extra mmol ammonium nitrate/l
6	+ 0,5
7	+ 0,75
8	+ 1,0

Sweet pepper (rock wool)

Combination class (see PPO book)	Extra mmol ammonium nitrate/l
6	+ 0,0
7	+ 0,3
8	+ 0,5

Sweet pepper (peat substrate)

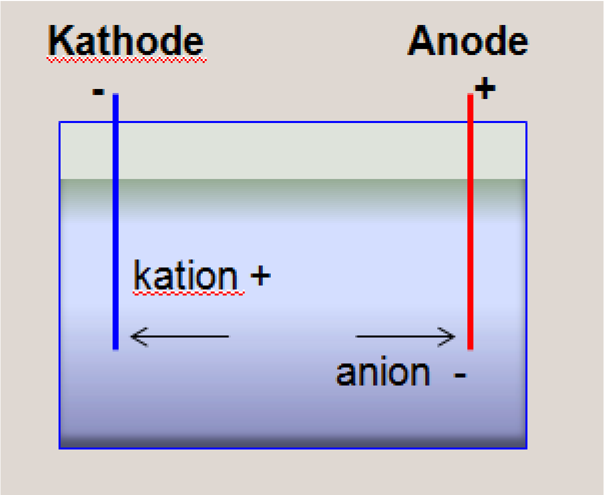
Combination class (see PPO book)	Extra mmol ammonium nitrate/l
6	+ 0,2
7	+ 0,4
8	+ 0,6

Source: WUR/PPO The Netherlands

Electric conductivity (EC)

Principle:

- More salt in solution = more ions = more conductivity = more electricity flow = higher EC value.
- The electric flow can be measured with an Ampere meter (EC meter).
- Unit: mS/cm^2 at 25^0C (former days: mho).
- Urea is <u>not</u> an ion and consequently it <u>don't</u> have an EC!

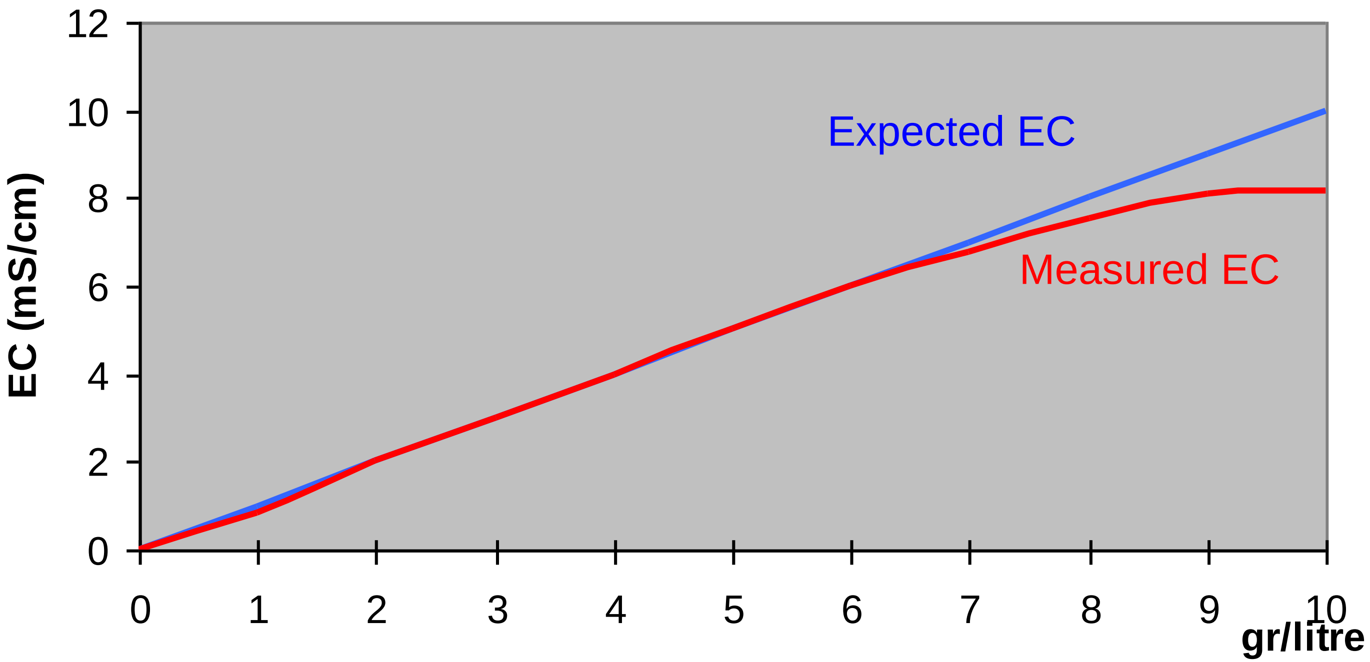


Advantage:
- Simple tool and can be used in a water flow.
- Commonly used world wide.

Disadvantage:
- <u>Urea</u> can not be measured.
- Plant doesn't work with EC.
- Useable in a limited range.

Electric conductivity (EC)

- Higher concentration of ions = more electric conductivity (EC).
- Question: if 1 gram fertilizer/l = 1 EC.   What will be the EC at 10 g/l ? ?



Caused by **Concentration polarization** of high concentrations of ions, urea, sugar, root exudates, high concentration of specific ions.

mmol/l versus ppm (mg/kg)

In (greenhouse) fertigation systems, concentration expressed

- In Netherlands, Belgium: mmol/l is common use
- The rest of the world use ppm or mg/kg.

First an question...

What do you see?

17 cows

or

10 200 kg cows

What is a mole?

- A mole a fixt number, like a dozen (12) that can describe a set of objects.
- A mole is the amount of substance which contains as many elementary entities as there are atoms in 0,012 kg (or 12 gram) of carbon (C).
- The number of atoms in 0,012 kilogram of carbon is known as Avogadro's constant (N_A). The currently accepted value is $6{,}0221415 \times 10^{23}\ mol^{-1}$.
- mole (symbol: mol) is a SI base unit

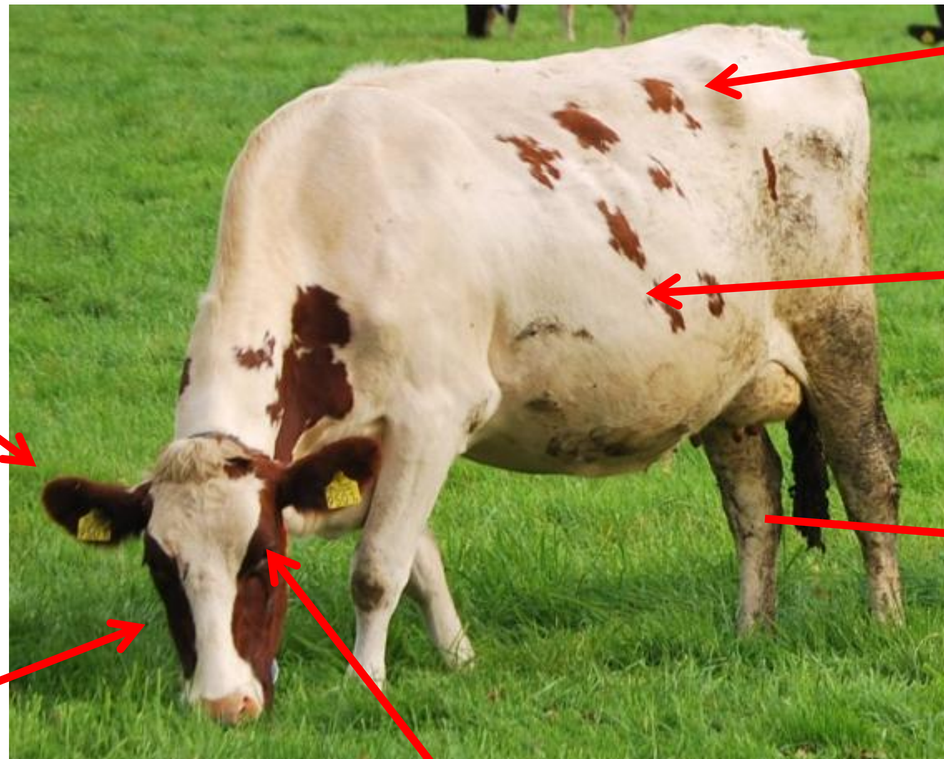
- 1 mol H^+ contains 6 x 10^{23} H^+ ions
- 1 mol H_2O contains 6 x 10^{23} H_2O molecules

- 1 mmol = 0,001 mol (6 x 10^{20})
- 1 µmol = 0,001 mmol (6 x 10^{17})

Lorenzo Avogadro 1776 – 1856 (Italy)

Mole

1 mole cow contains:



2 mole Sirloin beefs

4 mole stomachs

2 mole ears

4 mole legs

1 mole head

2 mole eyes

mole

The same principle for fertilisers:

- 1 mole KNO_3 → 1 mole K^+ and 1 mole NO_3^-
- 1 mole $Ca(NO_3)_2$ → 1 mole Ca^{2+} and 2 mole NO_3^-
- 1 mole K_2SO_4 → 2 mole K^+ and 1 mole SO_4^{2-}

Why mole? Lets look at the nutrient uptake first

- Fertilisers → Dissolves in water

  ↓ ↓

  Solid product → Ions in solution (cations and anions).

- The plant exchange ions in the rhizosphere and stays neutral.

- The mass of an ion is not relevant here.
- The number and ratio of ions is important!!
- The “language” of the crop is mole (particles) and not ppm (weight)!

And … Mole is simple!

- 1 mmol HPO_4 = 1 mmol P
  1 mmol NO_3^- = 1 mmol N
- 1 mmol K_2SO_4 gives: 2 mmol K + 1 mmol S or SO_4
- To neutralize 1 mmol HCO_3^- (bicarbonate) we need 1 mmol H^+

Conversion mole to weight

Mole to weight

mol x mol mass = gram

mmol x mol mass = mg

µmol x mol mass = µg

Weight to mole

gram / mol mass = mol

mg / mol mass = mmol

µg / mol mass = µmol

Mole mass (gram.mol^{-1})			
Al	26.98	Mg	24.31
B	10.81	Mn	54.94
Br	79.90	Mo	95.94
C	12.01	N	14.01
Ca	40.08	Na	22.99
Cl	35.45	O	16.00
Cu	63.55	P	30.97
Fe	55.85	S	32.06
H	1.01	Si	28.09
K	39.10	Zn	65.38

Example:

1 mole KNO_3 x mole mass = gram KNO_3

1 mole KNO_3 weights 101,1 gram

1 mmol/l KNO_3 x 101,1 = 101,1 mg KNO_3/l

101,1 mg/l ≈ 101,1 mg KNO_3/kg

101,1 mg/kg = 101,1 ppm KNO_3

So... WHY mole in fertigation?

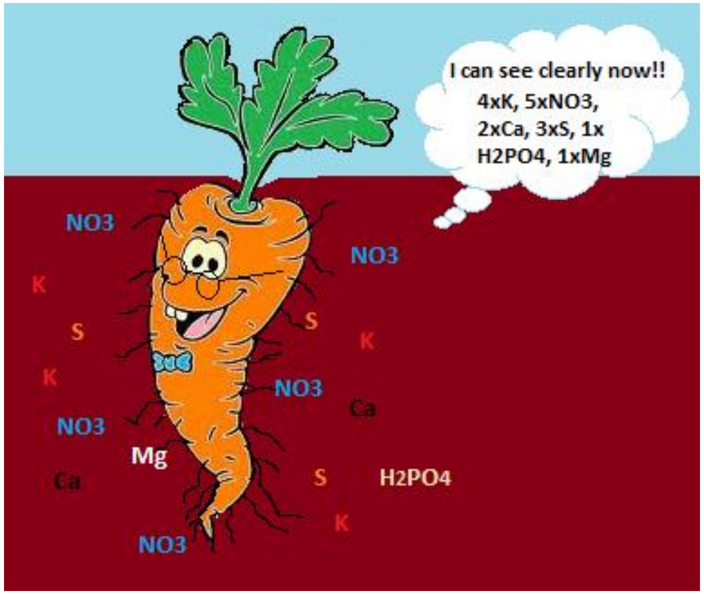
- Plant “knows” nothing about weight or percentage.
- Plants “recognize” the number of particles, ions, molecules, etc.

And...

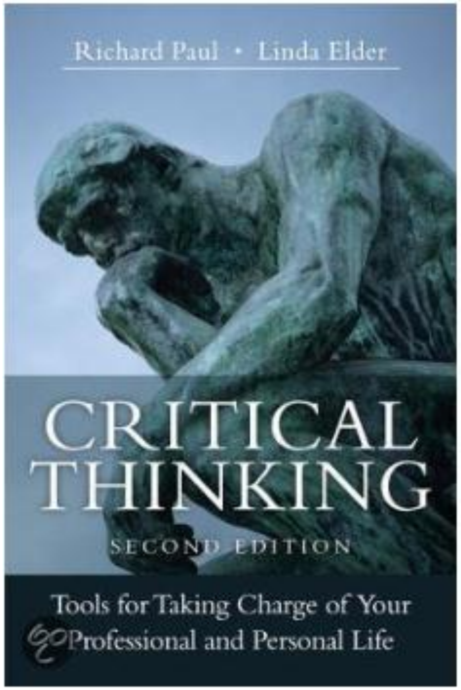
- Mole is easier for us. It’s better to understand what happened in the plant and in the rhizosphere.
- Easier in calculations.

So…

- Think in numbers!
- And the fact that a mole is a HUGH number is not important!



Are you convinced?
No… , mole is much better!



Ratio of nutrients are easy to understand.

Question: What is more for the plant:

46 ppm Na or 60 ppm K?

Answer: 46 ppm Na = 46 mg Na/kg ≈ 46 mg Na/l
46 mg Na/l /23 = 2,0 mmol Na/l

60 ppm K = 60 mg K/kg ≈ 60 mg K/l
60 mg K/l /39,1 = 1,5 mmol K/l

Conclusion: the plant “see” more sodium than potassium.

Sampling and analysis

Blgg Naaldwijk 20-04-2005

Klantnummer	: 6002056	Object code	:
Onderzoeknummer	: 306.470	Monsteraanduiding	:
Ordernummer	: 306.469	Monstername	
Datum monstername	: 14-04-2005		
Datum ontvangst	: 19-04-2005		
Code onderzoek	: 310		

Yara

Bemestingsonderzoek Glastuinbouw

	EC	pH	NH4	K	Na	Ca	Mg	NO3	Cl	SO4	HCO3	P	Si	Fe	Mn	Zn	B	Cu	Mo
	mS/cm.		mmol/l.										mmol/l.	µmol/l.					
Analyseresultate	4.7	6.2	< 0.1	8.5	0.6	12.5	6.5	26.3	0.8	7.5	2.0	1.25	0.50	35	6	8	65	0.9	0.6

- **Cation charge sum** (in mmol/l):
  - NH_4^+ - x 1 = -
  - K^+ 8,5 x 1 = 8,5
  - Na^+ 0,6 x 1 = 0,6
  - Ca^{2+} 12,5 x 2 = 25
  - Mg^{2+} 6,5 x 2 = 13 +

  Total: = 47,1

- **Anion charge sum** (in mmol/l):
  - NO_3^-: 26,3 x 1 = 26,3
  - Cl^-: 0,8 x 1 = 0,8
  - SO_4^{2-}: 7,5 x 2 = 15
  - HCO_3^-: 2,0 x 1 = 2
  - P^- 1,25 x 1 = 1,25 +

  Total: = 45,35

The cation charge sum and anion charge sum must be almost the same.

Sampling and analysis

- **EC (mS/cm) ≈** $\frac{\boldsymbol{cation\ charge\ sum}}{\mathbf{10}}$

  cation charge sum = 47,1

  $\frac{\boldsymbol{cation\ charge\ sum{=}47,1}}{\mathbf{10}}$ = 4,71

  EC analysis: 4,7 mS/cm

  EC (mS/cm) ≈ $\frac{\boldsymbol{anion\ charge\ sum}}{\mathbf{10}}$

  anion charge sum = 45,35

  $\frac{\boldsymbol{anion\ charge\ sum{=}\ 45,35}}{\mathbf{10}}$ = 4,53

  EC analysis: 4,7 mS/cm

- Relation pH and availability of ions:

Mn, Zn, Cu	**present**	**not present**
NH_4^+	**present**	**not present**
HCO_3^-	**not present**	**present**
$H_2PO_4^-$	**present**	**not present**
pH	**7**	**14**

Introduction of the Dutch advice system

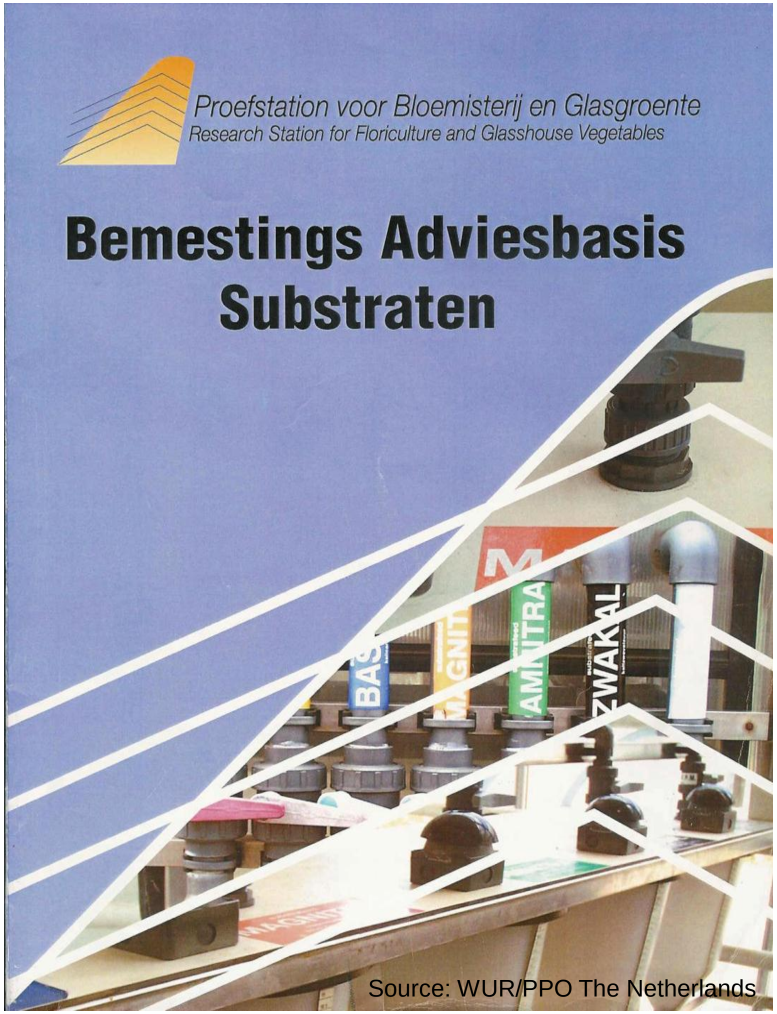
- The Dutch fertilization standard

  (ISSN 1387 – 2427 May 1999)

- Vegetables and Flowers

  in stone wool, peat, cocos

- Other standards:
  - pot plants,
  - soil greenhouse crops,
  - open field flowers.



Source: WUR/PPO The Netherlands

Fertilizing Advice-standard for Substrates (PPO)

3.2.2 A **Gewas : Tomaat (vrije drainage)**

Crop: Tomato (no recirculation)

Standaardvoedingsoplossing met EC = 2.6 Standard solution

NH₄	K	Ca	Mg	NO₃	SO₄	H₂PO₄	Fe	Mn	Zn	B	Cu	Mo
1.2	9.5	5.4	2.4	16.0	4.4	1.5	15	10	5	30	0.75	0.5

Streefcijfers op basis van EC(c) = 3.7 Standard EC target value

Target values

NH_4	K	Ca	Mg	NO_3	SO_4	P	pH	Fe	Mn	Zn	B	Cu
< 0.5	8.0	10.0	4.5	23.0	6.8	1.0	5.5	25	7	7	50	0.7

Waardering gecorrigeerd op EC(c) Interpretation of the analysis

Element		NH_4*	K	Na*	Ca	Mg	NO_3	Cl*	SO_4	P
Laag	<		6.5		8.0	2.7	17.0	2.5	4.0	0.70
Hoog	>	0.5	10.0	8.0	12.0	6.5	28.0	12.0	9.0	2.00
Buiten A.V.W.	<		3.5		4.5	1.4	7.0		1.7	0.25
" "	>	2.0	16.0	10.0	20.0	9.0	34.0	20.0	13.5	3.50

Waardering niet gecorrigeerd op EC(c)

		HCO_3	EC	pH	Fe	Mn	Zn	B	Cu
Laag	<		2.5	5.0**	18.0	3.0	5.0	35	0.5
Hoog	>	1.0	5.0	6.5	35.0	10.0	10.0	65	1.5
Buiten A.V.W.	<		1.5	6.0***	3.0	0.5	1.5	10	
" "	>	2.0	6.0	7.5	75.0	20.0	50.0	115	6.0

* Geen correctie EC(c) ** 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

Gewas : Tomaat (vrije drainage) Limits for corrections

Grenzen voor aanpassingen hoofdelementen bij EC(c)

	K	Ca	Mg	NO_3	SO_4	P
1	< 5.0	< 6.0		< 14.0		
2	5.0-6.4	6.0-7.9	> 2.7	14.0-16.9	< 4.0	< 0.70
3	6.5-10.0	8.0-12.0	2.7-6.5	17.0-28.0	4.0-9.0	0.70-2.00
4	10.1-13.0	12.1-15.0	> 6.5	28.1-30.0	> 9.0	> 2.00
5	> 13.0	> 15.0		> 30.0		

Grenzen voor aanpassingen spoorelementen

	Fe	Mn	Zn	B	Cu
1	< 15.0		< 3.0	< 15	< 0.3
2	15.0-17.9	< 3.0	3.0-4.9	15-34	0.3-0.4
3	18.0-35.0	3.0-10.0	5.0-10.0	35-65	0.5-1.5
4	35.1-50.0	10.1-15.0	10.1-15.0	66-90	1.6-2.5
5	> 50.0	> 15.0	> 15.0	> 90	> 2.5

Aanpassingen Corrections

	Hoofdelementen in mmol/l						Spoorelementen in %				
	K	Ca	Mg	NO_3	SO_4	P	Fe	Mn	Zn	B	Cu
1 +	3.0	1.5		3.0			50		50	50	50
2 +	1.5	0.75	0.5	1.5	0.5	0.25*	25	25	25	25	25
3	0	0	0	0	0	0	0	0	0	0	0
4 -	1.5	0.75	0.25	1.5	1.0	0.25	25	25	25	25	25
5 -	3.0	1.75		3.0			50	50	50	50	50

* Als pH < 6.5 aanpassing is 0.5 mmol/l

Correction of pH with NH_4^+

Extra aanpassing
factor K/Ca > 1.1

analyse-cijfer

K	Ca
6.5-10.0	8.0-12.0

Aanpassing
- 0.5 K
+ 0.25 Ca

Ammonium aanpassing

Combinatieklasse*	extra NH_4NO_3
pH/NH_4/HCO_3	mmol/l
6	0.4
7	0.6
8	0.8

* Voor combinatieklasse zie hoofdstuk 3

Ratio K/ Ca and corrections

Source: WUR/PPO The Netherlands

Analysis and Target values

Problem: EC in analysis report is never exact the target EC.
Target values of the nutrients are without Na and Cl
Na and Cl are not nutrients.
Na and Cl are part of the EC analysis.

So… for a fair comparison of the analysis with the target values:
- the EC must be the same as the target EC.
- and a correction is needed to eliminate the influence of Na^+ and Cl^- on the EC.

Different defined EC's:
- EC(v): the EC of the feeding nutrients (without Na^+ and Cl^-).
- EC(analysis): EC measured in the sample at the laboratory.
- EC(c): Fixed EC value (constant) with fit to the target values.

Analysis and Target values

- EC(v): the EC of the real nutrients (without Na^+ and Cl^-).
- EC(analysis): EC measured in the sample at the laboratory. (See lab report.)
- EC(c): Fixed EC value (constant) with fit to the target values. (See PPO book.)

Method to correct the nutrient concentrations:

1. EC(v) = EC analysis – (10% of mmol/l Na^+ or mmol/l Cl^-).
2. Na^+ or Cl^-: the highest concentration is used. Except when Cl^- is a nutrient (eg tomato)
3. Correction factor = EC(c) / EC(v).
4. When Cl is nutrient: The anion factor = EC(c) / EC(analysis
5. Nutrient concentrations **x** correction factor = final concentration.
6. Recalculate all nutrients, except: NH_4^+, Na^+, Cl^-, HCO_3^-, EC, pH and all micro nutrients.

Recalculation to the EC(c)

Example:

Crop: sweet pepper

EC(c): 2,7 mS/cm

EC(analysis): 3,5 mS/cm

Na^{+}: 2,5 mmol/l

Cl^{-}: 1,8 mmol/l

Ca^{2+}: 9,5 mmol/l

Mn^{2+}: 15 µmol/l

Step 1:

Define the highest: Na^{+} or Cl^{-} : Na^{+} = 2,5 mmol/l.

Step 2:

EC(v) = EC(analysis) – (10% of 2,5)

EC(v) = 3,5 – 0,25

EC(v) = 3,25 (this the real EC of nutrients)

Step 3:

Factor = EC(c)/ EC(v)

Factor = 2,7 / 3,25

Factor = 0,83

Ca^{2+} = 9,5 mmol/l by 3,5 EC but (9,5 x 0,83 =) 7,88 by 2,7 EC

Mn^{2+} = 15 µmol/l by 3,5 EC and will not be recalculate

Now the target values are valid and a fair comparison can be done!

Recalculated analysis and evaluation

Crop	**tomato**
Growth medium	Rock wool
Recirculation system	without recirculation
EC (c)	3,7 **mS/cm**
Crop stage	Start till first flower 3th tros
Desired EC drip water	4,2 **mS/cm**
Drain water usage	**%**

		mS/cm	**mmol/l**										**umol/l**					
Results of water analysis	**pH**	**EC**	**NH_4**	**K**	**Na**	**Ca**	**Mg**	**NO_3**	**Cl**	**SO_4**	**P**	**HCO_3**	**Fe**	**Mn**	**Zn**	**B**	**Cu**	**Mo**
analysis substrate	7,30	4,30	0,10	4,20	3,20	12,00	4,10	21,00	3,60	5,50	3,20		45,0	2,0	4,2	135,0	0,4	0,5
analysis drainage water																		

Evaluation substrate analysis	**pH**	**EC**	**NH_4**	**K**	**Na**	**Ca**	**Mg**	**NO_3**	**Cl**	**SO_4**	**P**	**HCO_3**	**Fe**	**Mn**	**Zn**	**B**	**Cu**	**Mo**
Analysis substrate	7,30	4,30	0,10	4,20	3,20	12,00	4,10	21,00	3,60	5,50	3,20		45,0	2,0	4,2	135,0	0,4	0,5
Corrected to EC(c) (use table A)			0,10	3,94		11,27	3,85	19,72		5,16	3,01		45,00	2,00	4,20	135,00	0,35	0,50
Evaluation	H	ok		L		ok	ok	ok		ok	h		h	l	l	AH	l	
Target values		3,70	< 0,5	8,00		10,00	4,50	23,00		6,80	1,00		25	7	7	50	0,7	

Table A: Conversion factor EC (c)		
EC laboratory (analysis)	**EC (a) =**	4,30
10 % of Na of Cl (highest)		0,36
EC (v) = EC (a) - 10% Na of Cl	**EC (v) =**	3,94
EC (c)	**EC (c) =**	3,7
Factor = EC (c) / EC (v)	**Factor =**	0,94
When Cl is nutrient, **anion factor**=EC (c) / EC (a):		

Summary of how to calculate a new advice

1. Recalculate the analysis to the EC (c).
2. Compare the recalculated values with the interpretation; (high, low, outside).
3. Fill in the target values.
4. Fill in the standard solution.
5. Define the necessary correction, based on the analysis results, incl. drip EC.
6. Fill in the input of the drain water (at the right % usage).
7. Make a draft sum: standard solution +/- all corrections.
8. Correct the charge unbalance of the ions.

See also page 142 – 145 of the WUR/PPO Substrate book for all details.

Calculation of a recipe

Crop	**tomato**	
Growth medium	Rock wool	
Recirculation system	without recirculation	
EC (c)	3,7	**mS/cm**
Crop stage	Start till first flower 3th tros	
Desired EC drip water	4,2	**mS/cm**
Drain water usage		**%**

mmol/l	**HCO_3**	**Ca**
Input water source	3,10	1,25

		mS/cm	**mmol/l**										**umol/l**					
Results of water analysis	**pH**	**EC**	**NH_4**	**K**	**Na**	**Ca**	**Mg**	**NO_3**	**Cl**	**SO_4**	**P**	**HCO_3**	**Fe**	**Mn**	**Zn**	**B**	**Cu**	**Mo**
analysis substrate	7,30	4,30	0,10	4,20	3,20	12,00	4,10	21,00	3,60	5,50	3,20		45,0	2,0	4,2	135,0	0,4	0,5
analysis drainage water																		

Evaluation substrate analysis	**pH**	**EC**	**NH_4**	**K**	**Na**	**Ca**	**Mg**	**NO_3**	**Cl**	**SO_4**	**P**	**HCO_3**	**Fe**	**Mn**	**Zn**	**B**	**Cu**	**Mo**
Analysis substrate	7,30	4,30	0,10	4,20	3,20	12,00	4,10	21,00	3,60	5,50	3,20		45,0	2,0	4,2	135,0	0,4	0,5
Corrected to EC (c) (use table A)			0,10	3,94		11,27	3,85	19,72		5,16	3,01		45,00	2,00	4,20	135,00	0,35	0,50
Evaluation	H	ok		L		ok	ok	ok		ok	h		h	l	l	AH	l	
Target values		3,70	< 0,5	8,00		10,00	4,50	23,00		6,80	1,00		25	7	7	50	0,7	

Recipe Calculation	**pH**	**EC**	**NH_4**	**K**	**Na**	**Ca**	**Mg**	**NO_3**	**Cl**	**SO_4**	**P**	**H+**	**Fe**	**Mn**	**Zn**	**B**	**Cu**	**Mo**
Standard nutrition		2,63	1,20	9,50		5,40	2,40	16,00		4,40	1,50		15,00	10,00	5	30	0,75	0,5
Correction based on substrate																		
Correction according to crop stage																		
Total after corrections																		
Recipe at desired EC																		
Minus: input drainage water																		
Minus: input raw water																		
Result before equilibrium +/- ions																		
Result after equilibrium (use table B)																		
New fertiliser recipe																		

Define the correction based on the analysis.

- Compare the recalculated value with the limits (class) for corrections.

Class 1.	< 5,0 mmol/l
2.	5,0 – 6,4
3.	6,5 – 10,0
4.	10,1 – 13,0
5.	> 13,0

Example: K^+ = 3,94 mmol/l by EC (c)
K^+ fit in class 1: < 5,0 mmol/l

- Find the corresponding correction of the same class and nutrient.

Class 1.	+ 3,0 mmol/l
2.	+ 1,5
3.	0
4.	- 1,5
5.	- 3,0

Example: K^+ in class 1
K^+ correction = **+ 3,0 mmol/l**

- New concentration: standard solution + correction, eg: 9,5 + 3,0 = 12,5 mmol/l
- Corrections of Micro nutrients are in % of the standard solution.

The corrections, incl. pH

Crop	**tomato**
Growth medium	Rock wool
Recirculation system	without recirculation
EC (c)	3,7 **mS/cm**
Crop stage	Start till first flower 3th tros
Desired EC drip water	4,2 **mS/cm**
Drain water usage	**%**

Evaluation substrate analysis	pH	EC	NH_4	K	Na	Ca	Mg	NO_3	Cl	SO_4	P	HCO_3	Fe	Mn	Zn	B	Cu	Mo
Analysis substrate	7,30	4,30	0,10	4,20	3,20	12,00	4,10	21,00	3,60	5,50	3,20		45,0	2,0	4,2	135,0	0,4	0,5
Corrected to EC (c) (use table A)			0,10	3,94		11,27	3,85	19,72		5,16	3,01		45,00	2,00	4,20	135,00	0,35	0,50
Evaluation	H	ok		L		ok	ok	ok		ok	h		h	l	l	AH	l	
Target values		3,70	< 0,5	8,00		10,00	4,50	23,00		6,80	1,00		25	7	7	50	0,7	

Recipe Calculation	pH	EC	NH_4	K	Na	Ca	Mg	NO_3	Cl	SO_4	P	H+	Fe	Mn	Zn	B	Cu	Mo
Standard nutrition		2,63	1,20	9,50		5,40	2,40	16,00		4,40	1,50		15,00	10,00	5	30	0,75	0,5
Correction based on substrate			0,40	3,00							-0,25		-3,75	2,50	1,25	-15,00	0,19	
Correction according to crop stage				-1,00		0,50	0,50	1,00										
Total after corrections		**2,89**	**1,60**	**11,50**		**5,90**	**2,90**	**17,00**		**4,40**	**1,25**		**11,25**	**12,50**	**6,25**	**15,00**	**0,94**	**0,50**

Table C: pHmanagement		
NH_4 in analysis	0,10	mmol/l
HCO_3 in analysis	-	mmol/l
pH in analysis	7,30	
Combination group (1 - 8)	6	
Extra NH_4 (group 6-7-8)	**+ 0,4**	mmol/l

Recalculated to the desired EC

Crop	**tomato**
Growth medium	Rock wool
Recirculation system	without recirculation
EC (c)	3,7 **mS/cm**
Crop stage	Start till first flower 3th tros
Desired EC drip water	4,2 **mS/cm**
Drain water usage	**%**

Recipe Calculation	**pH**	**EC**	**NH_4**	**K**	**Na**	**Ca**	**Mg**	**NO_3**	**Cl**	**SO_4**	**P**	**H+**	**Fe**	**Mn**	**Zn**	**B**	**Cu**	**Mo**
Standard nutrition		2,63	1,20	9,50		5,40	2,40	16,00		4,40	1,50		15,00	10,00	5	30	0,75	0,5
Correction based on substrate			0,40	3,00							-0,25		-3,75	2,50	1,25	-15,00	0,19	
Correction according to crop stage				-1,00		0,50	0,50	1,00										
Total after corrections		**2,89**	**1,60**	**11,50**		**5,90**	**2,90**	**17,00**		**4,40**	**1,25**		**11,25**	**12,50**	**6,25**	**15,00**	**0,94**	**0,50**
Recipe at desired EC		4,16	1,60	16,73		8,58	4,22	24,73		6,40	1,82		11,25	12,5	6,25	15	0,94	0,5
Minus: input drainage water																		
Minus: input raw water																		
Result before equilibrium +/- ions																		
Result after equilibrium (use table B)																		
New fertiliser recipe																		

Used formula: (desired EC / EC after corrections) x nutrient.
NH_4^+, H^+ and micronutrients are not effected by EC.

Improved formula:
Cations: ((desired EC – (0,1x NH_4^+)) / (EC after corrections – (0,1x NH_4^+))) x cation.
Anions: (desired EC / EC after corrections) x anion.

Take into account the water source and the draft recipe.

mmol/l	HCO_3	Ca
Input water source	3,10	1,25

Recipe Calculation	pH	EC	NH_4	K	Na	Ca	Mg	NO_3	Cl	SO_4	P	H+	Fe	Mn	Zn	B	Cu	Mo
Standard nutrition		2,63	1,20	9,50		5,40	2,40	16,00		4,40	1,50		15,00	10,00	5	30	0,75	0,5
Correction based on substrate			0,40	3,00							-0,25		-3,75	2,50	1,25	-15,00	0,19	
Correction according to crop stage				-1,00		0,50	0,50	1,00										
Total after corrections		**2,89**	**1,60**	**11,50**		**5,90**	**2,90**	**17,00**		**4,40**	**1,25**		**11,25**	**12,50**	**6,25**	**15,00**	**0,94**	**0,50**
Recipe at desired EC		4,16	1,60	16,73		8,58	4,22	24,73		6,40	1,82		11,25	12,5	6,25	15	0,94	0,5
Minus: input drainage water																		
Minus: input raw water						-1,25						2,50						
Result before equilibrium +/- ions		4,16	**1,60**	**16,73**		**7,33**	**4,22**	**24,73**		**6,40**	**1,82**	**2,50**	**11,3**	**12,5**	**6,3**	**15,0**	**0,94**	**0,50**
Result after equilibrium (use table B)																		
New fertiliser recipe																		

Check if the cation vs anion charge sum are in balance:

Equivalent cations $= NH_4^+ + K^+ + Na^+ + (2x\ Ca^{2+}) + (2x\ Mg^{2+}) + H^+$

$= 1,6 + 16,73 + 0 + (2x\ 7,33) + (2x\ 4,22) + 2,50$

= 43,93

Equivalent anions $= NO_3^- + Cl^- + (2x\ SO_4^{2-}) + HCO_3^- + H_2PO_4^-$

$= 24,73 + 0 + (2x\ 6,40) + 0 + 1,82$

= 39,35

The unbalance must be corrected by equilibrium.

Final recipe after balancing the ions

Recipe Calculation	pH	EC	NH_4	K	Na	Ca	Mg	NO_3	Cl	SO_4	P	H+	Fe	Mn	Zn	B	Cu	Mo
Standard nutrition		2,63	1,20	9,50		5,40	2,40	16,00		4,40	1,50		15,00	10,00	5	30	0,75	0,5
Correction based on substrate			0,40	3,00							-0,25		-3,75	2,50	1,25	-15,00	0,19	
Correction according to crop stage				-1,00		0,50	0,50	1,00										
Total after corrections		**2,89**	**1,60**	**11,50**		**5,90**	**2,90**	**17,00**		**4,40**	**1,25**		**11,25**	**12,50**	**6,25**	**15,00**	**0,94**	**0,50**
Recipe at desired EC		4,16	1,60	16,73		8,58	4,22	24,73		6,40	1,82		11,25	12,5	6,25	15	0,94	0,5
Minus: input drainage water																		
Minus: input raw water						-1,25						2,50						
Result before equilibrium +/- ions		4,16	**1,60**	**16,73**		**7,33**	**4,22**	**24,73**		**6,40**	**1,82**	**2,50**	**11,3**	**12,5**	**6,3**	**15,0**	**0,94**	**0,50**
Result after equilibrium (use table B)		**4,16**	**1,60**	**15,77**		**6,91**	**3,98**	**26,24**		**6,79**	**1,82**	**2,50**	**11,3**	**12,5**	**6,3**	**15,0**	**0,94**	**0,50**
New fertiliser recipe		**4,20**	**1,60**	**15,77**		**6,91**	**3,98**	**26,24**		**6,79**	**1,82**	**2,50**	**11,3**	**12,5**	**6,3**	**15,0**	**0,94**	**0,50**

Check if the cation vs anion charge balance are in balance:

Equivalent cations = NH_4^+ + K^+ + Na^+ + (2x Ca^{2+}) + (2x Mg^{2+}) + H^+
= **1,60** + 15,77 + 0 + (2x 6,91) + (2x 3,98) + **2,50**
= 41,64

Equivalent anions = NO_3^- + Cl^- + (2x SO_4^{2-}) + HCO_3^- + $H_2PO_4^-$
= 26,24 + 0 + (2x 6,79) + 0 + **1,82**
= 41,64

No correction: NH_4^+, H^+ , $H_2PO_4^-$ and micro nutrients.

The final result

Crop	**tomato**
Growth medium	Rock wool
Recirculation system	without recirculation
EC (c)	3,7 **mS/cm**
Crop stage	Start till first flower 3th tros
Desired EC drip water	4,2 **mS/cm**
Drain water usage	**%**

mmol/l	HCO_3	Ca
Input water source	3,10	1,25

		mS/cm	mmol/l										umol/l					
Results of water analysis	**pH**	**EC**	**NH_4**	**K**	**Na**	**Ca**	**Mg**	**NO_3**	**Cl**	**SO_4**	**P**	**HCO_3**	**Fe**	**Mn**	**Zn**	**B**	**Cu**	**Mo**
analysis substrate	7,30	4,30	0,10	4,20	3,20	12,00	4,10	21,00	3,60	5,50	3,20		45,0	2,0	4,2	135,0	0,4	0,5
analysis drainage water																		

Evaluation substrate analysis	**pH**	**EC**	**NH_4**	**K**	**Na**	**Ca**	**Mg**	**NO_3**	**Cl**	**SO_4**	**P**	**HCO_3**	**Fe**	**Mn**	**Zn**	**B**	**Cu**	**Mo**
Analysis substrate	7,30	4,30	0,10	4,20	3,20	12,00	4,10	21,00	3,60	5,50	3,20		45,0	2,0	4,2	135,0	0,4	0,5
Corrected to EC (c) (use table A)			0,10	3,94		11,27	3,85	19,72		5,16	3,01		45,00	2,00	4,20	135,00	0,35	0,50
Evaluation	H	ok		L		ok	ok	ok		ok	h		h	l	l	AH	l	
Target values		3,70	< 0,5	8,00		10,00	4,50	23,00		6,80	1,00		25	7	7	50	0,7	

Recipe Calculation	**pH**	**EC**	**NH_4**	**K**	**Na**	**Ca**	**Mg**	**NO_3**	**Cl**	**SO_4**	**P**	**H+**	**Fe**	**Mn**	**Zn**	**B**	**Cu**	**Mo**
Standard nutrition		2,63	1,20	9,50		5,40	2,40	16,00		4,40	1,50		15,00	10,00	5	30	0,75	0,5
Correction based on substrate			0,40	3,00							-0,25		-3,75	2,50	1,25	-15,00	0,19	
Correction according to crop stage				-1,00		0,50	0,50	1,00										
Total after corrections		**2,89**	**1,60**	**11,50**		**5,90**	**2,90**	**17,00**		**4,40**	**1,25**		**11,25**	**12,50**	**6,25**	**15,00**	**0,94**	**0,50**
Recipe at desired EC		4,16	1,60	16,73		8,58	4,22	24,73		6,40	1,82		11,25	12,5	6,25	15	0,94	0,5
Minus: input drainage water																		
Minus: input raw water						-1,25						2,50						
Result before equilibrium +/- ions		4,16	**1,60**	**16,73**		**7,33**	**4,22**	**24,73**		**6,40**	**1,82**	**2,50**	**11,3**	**12,5**	**6,3**	**15,0**	**0,94**	**0,50**
Result after equilibrium (use table B)		**4,16**	**1,60**	**15,77**		**6,91**	**3,98**	**26,24**		**6,79**	**1,82**	**2,50**	**11,3**	**12,5**	**6,3**	**15,0**	**0,94**	**0,50**
New fertiliser recipe		**4,16**	**1,60**	**15,77**		**6,91**	**3,98**	**26,24**		**6,79**	**1,82**	**2,50**	**11,3**	**12,5**	**6,3**	**15,0**	**0,94**	**0,50**

Specification straight fertilisers

Straight fertilizer

Product	Formula	MW	density	1mmol 1000 L, 100x		Input Cation in mmol/l				Input in Anion in mmol/l				Base Acid input	
		gram/mol	kg/l	kg	liter	NH_4^+	K^+	Ca^{2+}	Mg^{2+}	NO_3^-	Cl^-	SO_4^{2-}	H_2PO_4	HCO_3^-	H^+
CalciNit	$5Ca(NO_3)_2+1NH_4NO_3.10H_2O$	216,1		21,6		0,2		1		2,2					
Krista K	KNO_3	101,1		10,1			1			1					
Krista SOP	K_2SO_4	174,3		17,4			2					1			
Krista MKP	KH_2PO_4	136,1		13,6			1						1		
Krista MAP	$NH_4H_2PO_4$	115,0		11,5		1							1		
Krista MgS	$MgSO_4.7H_2O$	246,4		24,6					1			1			
Magnitra Liquid	$Mg(NO_3)_2$	(400)	1,35	40,0	29,6				1	2					
Amnitra Liquid	NH_4NO_3	(156)	1,24	15,6	12,5	1				1					
Calsal Liquid	$Ca(NO_3)_2$	(320)	1,50	32,0	21,3			1		2					
Nitric acid 37%	HNO_3	(167)	1,24	16,7	13,5					1					1
Phosphoric acid 59%	H_3PO_4	(167)	1,42	16,7	11,8								1		1
Potassium carbonate	$KHCO_3$	100,1		10,0			1							1	
Ureum	$CO(NH_2)_2$	60		6,0		2 NH_2									

Calcinit : 1 mol Ca, 2.2 mol NO3 and 0.2 mol NH4 5Ca(NO3)2. XH2O + 1 NH4NO3.y H2O (x + y = 10)

(...) = calculated mole weight

Mole mass of fertilisers

- Use always the official mole mass of a product, don't calculate!.
- **Easy example:** Krista K
  - Formula: KNO_3
  - Mole mass: 101,1 g/mole ($g.mole^{-1}$)
  - Input in mole: 1 mole K^+ and 1 mole NO_3^-
  - Input of 101,1 g Krista K: 1 mole K^+ and 1 mole NO_3^-
- **Complex example**: Calcinit
  - Formula: $5Ca(NO_3)_2 \cdot_X H_2O + 1NH_4NO_3 \cdot_y H_2O$ (x + y = 10)
  - mole mass: 1080,5 g/mole ($g.mole^{-1}$)
  - Input in mole: 5 mole Ca^{2+} and 11 mole NO_3^- and 1 mole NH_4^+
  - Input of 216,1 g Calcinit: 1 mole Ca^{2+} and 2,2 mole NO_3^- and 0,2 mole NH_4^+

From mmol to kg

Tank size: 1000 litre.
Concentration:100x concentrated.
1000 l x 100x conc. = 100 000 l

Needed: 1 mmol K^+/l drip water.
100 000 litre drip water.

Question: How much kg Krista K is needed for 1 mmol K/l (in drip water).

1 mmol K^+/l = 0,001 mol K^+/l.

Mole x mole mass = gram/l

0,001 mole/l x 101,1 = 0,1011 gr /l.

0,1011 gram/l = 10 110 gram for 100 000 litre.

10 110 gram for 100 000 litre = 10,1 kg / 100 000 litre,1x concentrated.
= 10,1 kg / 1000 litre, 100x concentrated.

Mole mass KNO_3 = 101,1 g/mole

From mmol to kg

Needed: 1 mmol Ca^{2+}/l drip water

100 000 litre drip water.

Tank size: 1000 litre.
Concentration:100x concentrated.
1000 l x 100x conc. = 100 000 l

Question: How much Calcinit is needed for 1 mmol Ca^{2+}/l

1 mmol Ca^{2+}/l	= 0,001 mol Ca^{2+}/l
Mole x mole mass	**= gram/l**
0,001 mole/l x 216,1	= 0,216 gr/l.
0,216 gram/l	= 21 600 gram for 100 000 litre.

21 600 gram for 100 000 litre = 21,6 kg / 100 000 litre, 1x concentrated.

= 21,6 kg / 1000 litre, 100x concentrated.

Mole mass Calcinit = $5Ca(NO_3)_2 + 1NH_4NO_3.10H_2O$ = 1080,5 g/mole
1 mole Ca^{2+} /l = 1080,5 / 5 = 216,1 g/mole

How to calculate a recipe from mmol/l to kg.

1. If acid is needed start with input mmol H^+/l. Start with Nitric acid.
2. (Fill in input of mmol Cl^-/l with CaCl or KCl.)
3. Fill in input of mmol Ca^{2+}/l.

   In case Calcinit is used, ratio in Calcinit: 1,0 Ca^{2+} gives also: 0,2 NH_4^+ and 2,2 NO_3^-
4. Fill the rest of NH_4^+ by using ammonium nitrate.
5. Determine the lowest needed (rest) concentration, probably: Mg^{2+}, SO_4^{2-}, HPO_4^{2-}

   Determine the nutrient and choose the best fitted Fertiliser.

   Fill in the right amount of secondary ions.
6. Repeat step 4 & 5, till all the ions are filled in.
7. Last fertiliser is (often) KNO_3.
8. Check if all nutrients are distributed fully and correctly.
9. Take into account tank size and concentration.

From mmol to kg fertilisers.

Tank size	1000	Litre
Concenetration	100	x
total nutrient solution	100000	Litre

Fertiliser		Tank	mmol fertiliser /l	1 mmol/l = .. kg	kg fertiliser	density	litre fertiliser	Recipe in mmol and mmol/l distribution							
								NH_4^+	K^+	Ca^{2+}	Mg^{2+}	NO_3^-	SO_4^{2-}	$H_2PO_4^-$	H^+
								1,60	**15,77**	**6,91**	**3,98**	**26,24**	**6,79**	**1,82**	**2,50**
Calcinit		A	**6,91**	**21,6**	**149,3**	-		1,38		***6,91***		15,20			
Krista K plus		A / B	**8,32**	**10,1**	**84,0**	-			***8,32***			8,32			
Krista SOP		B	**2,81**	**17,4**	**48,9**	-			5,62				***2,81***		
Krista MKP		B	**1,82**	**13,6**	**24,8**	-			1,82					***1,82***	
Krista MAP		B		**11,5**		-									
Krista MgS		B	**3,98**	**24,6**	**97,9**	-					***3,98***		3,98		
Krista MAG		A / B		**25,6**		-									
Magnesiumnitrate	**Liquid**	A / B		**40,0**		**1,35**									
Ammoniumnitrate	**Liquid**	A / B	**0,22**	**15,6**	**3,4**	**1,24**	**2,7**	***0,22***				0,22			
Calsal	**Liqiuid**	A		**32,1**		**1,50**									
Nitric Acid 38%	**Liquid**	A / B	**2,50**	**16,7**	**41,8**	**1,24**	**33,7**					2,50			***2,50***
Phosphoric acid 59%	**Liquid**	B		**16,7**		**1,42**									
							Rest	-	-	-	-	-	-	-	-

What do the grower: “Full Bag program”

Tank size	1000	Litre
Concenetration	100	x
total nutrient solution	100000	Litre

Fertiliser		Tank	mmol fertiliser /l	1 mmol/l = .. kg	*Recipe Kg*	Grower kg	density	litre fertiliser	Recipe in mmol and mmol/l distribution							
									NH_4^+	K^+	Ca^{2+}	Mg^{2+}	NO_3^-	SO_4^{2-}	$H_2PO_4^-$	H^+
									1,60	15,77	6,91	3,98	26,24	6,79	1,82	2,50
Calcinit		A	6,94	21,6	*149,3*	150,0	-		1,39		*6,94*		15,28			
Krista K plus		A / B	7,43	10,1	*84,0*	75,0	-			*7,43*			*7,43*			
Krista SOP		B	2,87	17,4	*48,9*	50,0	-			5,75				*2,87*		
Krista MKP		B	1,84	13,6	*24,8*	25,0	-			1,84					*1,84*	
Krista MAP		B		11,5			-									
Krista MgS		B	4,07	24,6	*97,9*	100,0	-					*4,07*		4,07		
Krista MAG		A / B		25,6			-									
Magnesiumnitrate	Liquid	A / B		40,0			1,35									
Ammoniumnitrate	Liquid	A / B	-	15,6	*3,4*	-	1,24	-	-				-			
Calsal	Liqiuid	A		32,1			1,50									
Nitric Acid 38%	Liquid	A / B	2,50	16,7	*41,8*	41,8	1,24	33,7					2,50			*2,50*
Phosphoric acid 59%	Liquid	B		16,7			1,42									
								Difference	- 0,21	- 0,76	0,03	0,09	- 1,03	0,15	0,02	

We all try to make a precise nutrient solution and then it goes wrong at the end!

A and B tank and acid

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.

When pH is too low: below < 5,0:

- Too acid for plant-roots.
- Rock wool start to dissolve.

Chelates in Horticulture: practical stability

- Chelate stability depends on pH level.
- Chelate metal-ion combination also determines stability.
- High temperature (>40C), UV radiation, (sun)light, Cu, Mn and Zn presence have negative influence on the chelate.

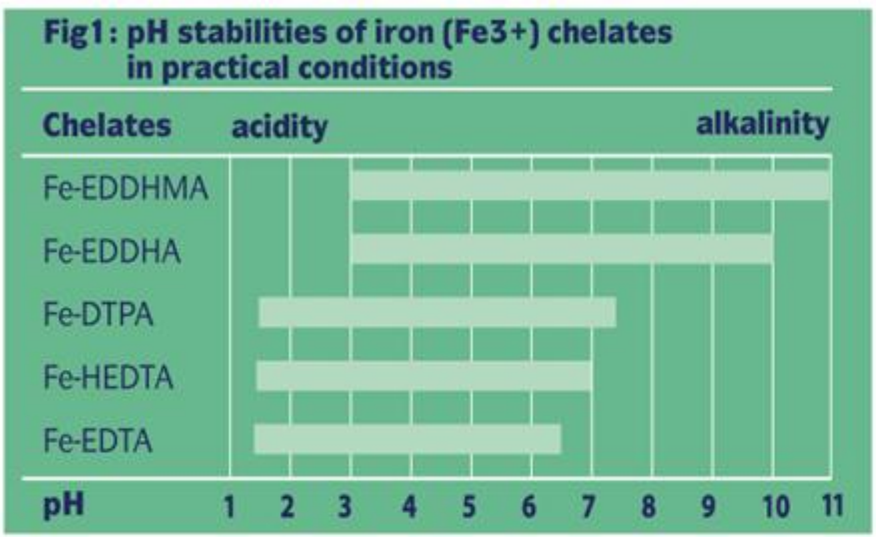


Fig1 : pH stabilities of iron (Fe3+) chelates in practical conditions

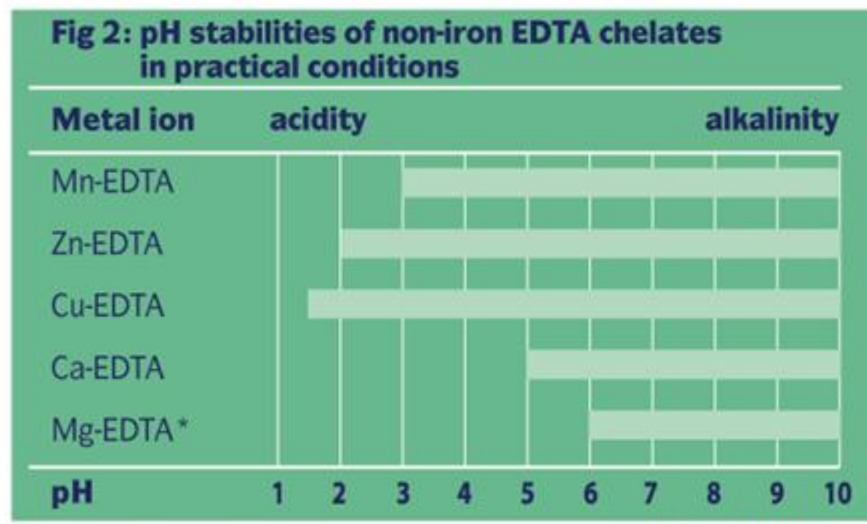
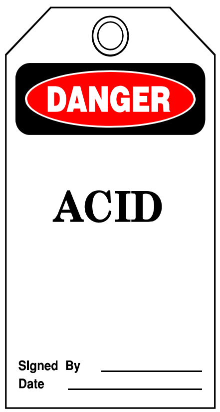


Fig 2: pH stabilities of non-iron EDTA chelates in practical conditions

*except at high Ca levels

source: Akzo Nobel

Handling of acids.



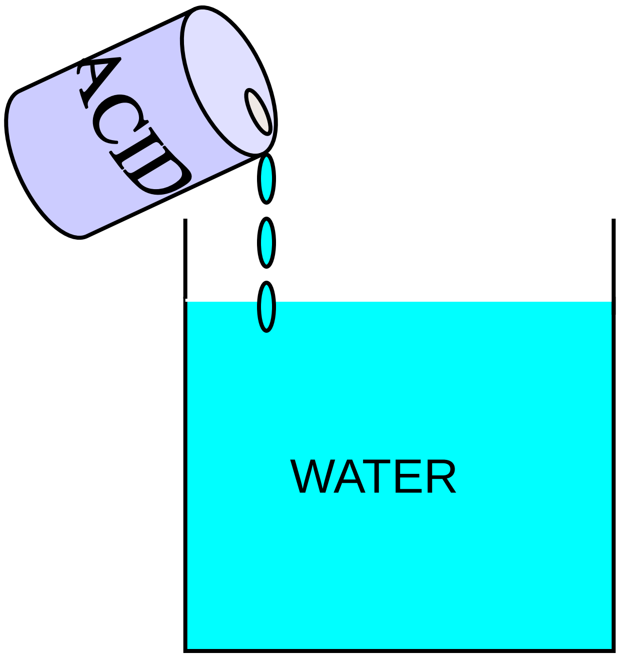
CLEARLY LABEL
WHERE ACIDS
ARE STORED

ALWAYS WEAR SUITABLE PROTECTIVE CLOTHING AND GLOVES WHEN USING ACIDS

A strong acid and water is a dangerous combination

Handling of acids.

<u>Always</u> add acid to water, <u>never</u> water to acid.



And…
don't forget to wear protective clothing and gloves.

Dangerous combinations

Acid + Base

- **Nitric acid + potassiumcarbonate**
  - Explosive reaction + heat
  - Tank can explode
- **Nitric acid + potassium hydroxide**
  - Violent reaction with enormous heat development
  - Tank can melt away

An **hydroxide** is even more dangerous than acid:
- Difficult too remove.
- It don’t burn on your skin: too late warning!!

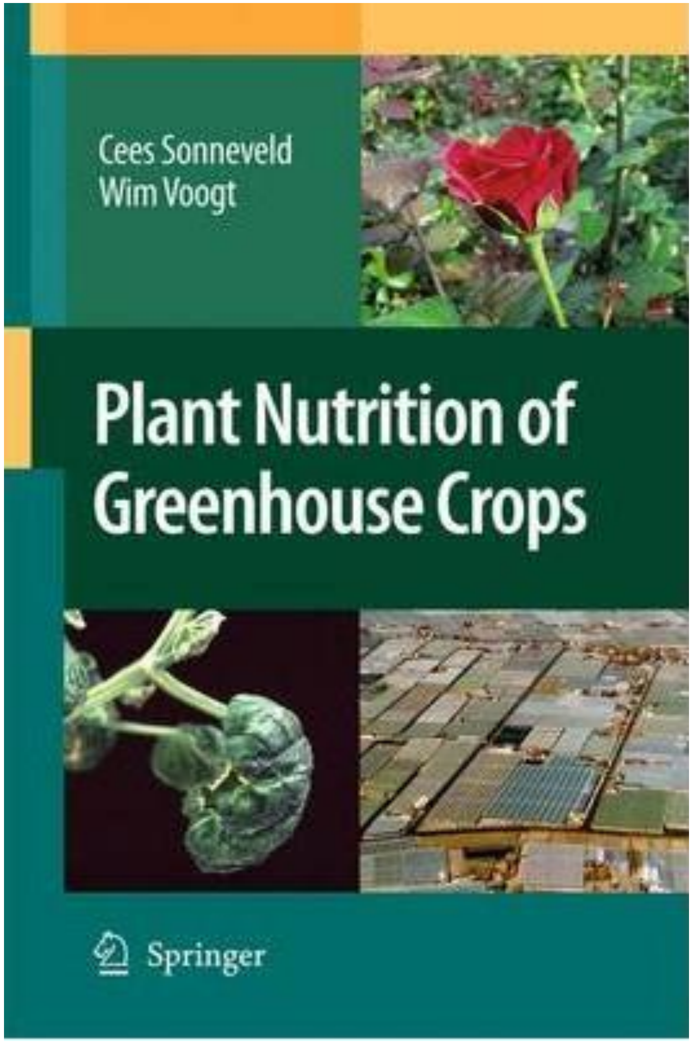
Safety

- **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.

New Fertilization book.



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YARA
Knowledge grows
Calcium:
The nutrient who needs your help!
Part 3

The Problem: Calcium deficiency

Blossom end rot in Sweet Pepper and Tomato

↓

Low Calcium concentration in the fruit

Calcium in short

- Calcium is important for cell strength and working of the membranes.
- Calcium uptake process is difficult and is fully linked with water uptake.
- Calcium redistribution in the plant does not happen.
- Plant parts which do not evaporate water quickly, show deficiency symptoms.
- Calcium is not the same as Chalk or Lime.
- Calcium needs help!

Potassium in short

Potassium is:

- Important Cation to the plant.
- Present in all plant tissues.
- Very mobile in the plant.
- Part of many reactions : physiological and chemical.
- Depended to the soil type susceptible to soil fixation.

Ca concentrations in plant sap and substrate.

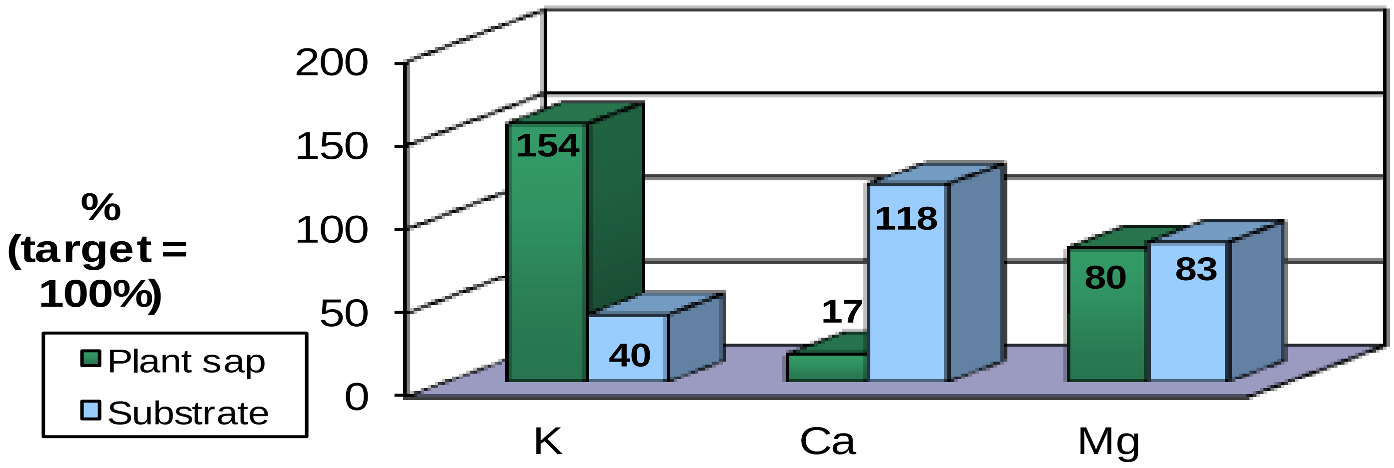
What we saw in a trial:

	Calcium	Potassium
Leaf : (Plant sap)	Low	High
Substrate:	High	Low

Plant sap: only mobile nutrients.
Dry matter: all nutrients.

Plant sap vs Substrate

	Potassium	Calcium
Uptake by root	Active	Passive
Mobility in plant	Very good	Very low



Plant sap vs Substrate

What should the new recommendation be:

Based on	Potassium	Calcium
Plant sap	less	more
Substrate	more	less

Based on plant sap:

K in Plant sap is very high and the new recommendation is **less** K.

Ca in plant sap is low, new recommendation more.

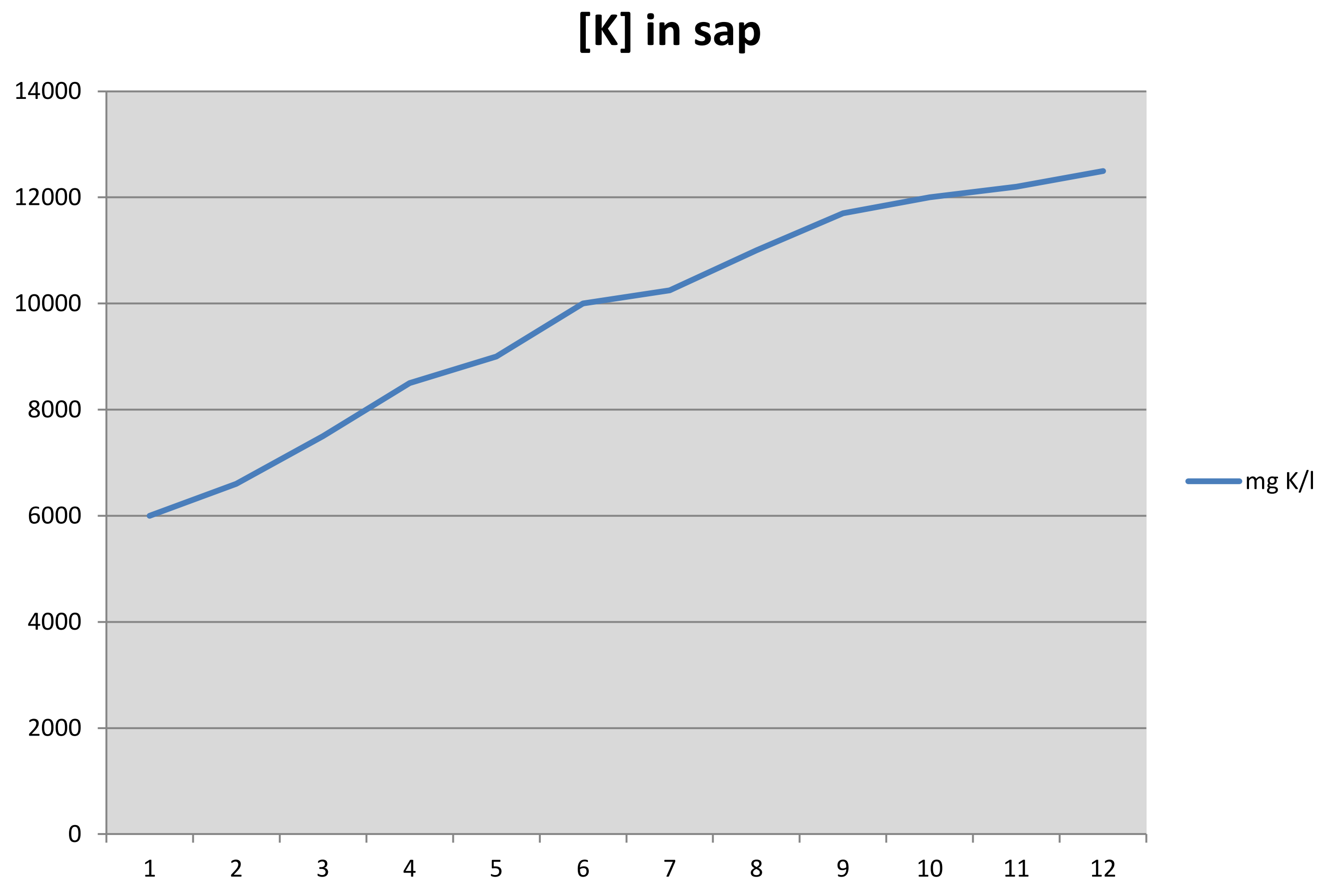
Base on Substrate:

Due to strong K uptake, the concentration of K in substrate is low.

The new recommendation is **more** K (Very common practice).

Ca in substrate is high, new recommendation is **less** Ca.

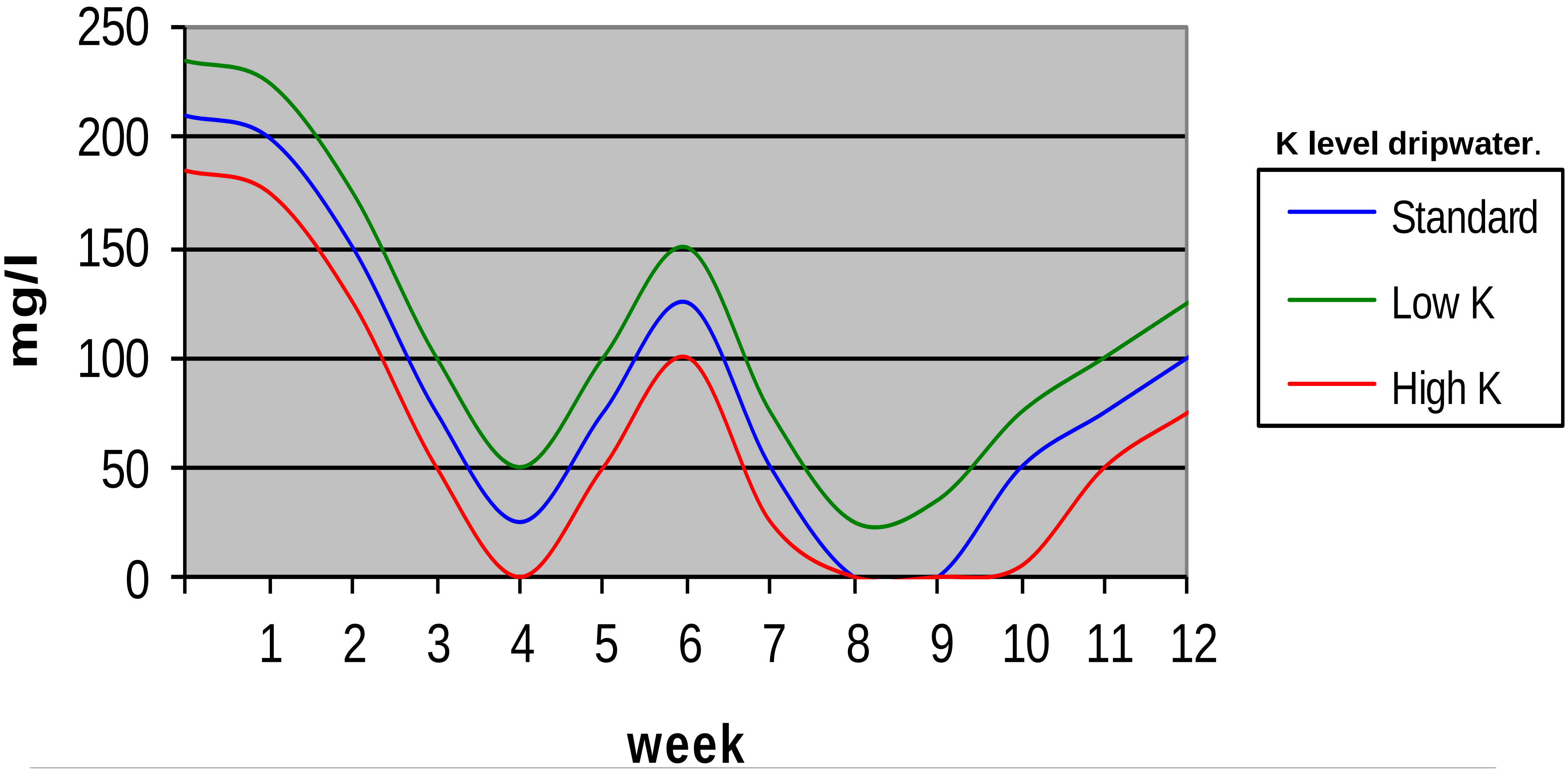
Potassium in plant sap during growth



Due to active uptake : high concentrations in sap

Calcium concentration in plant sap during growth

at different levels of K supply in drip water.

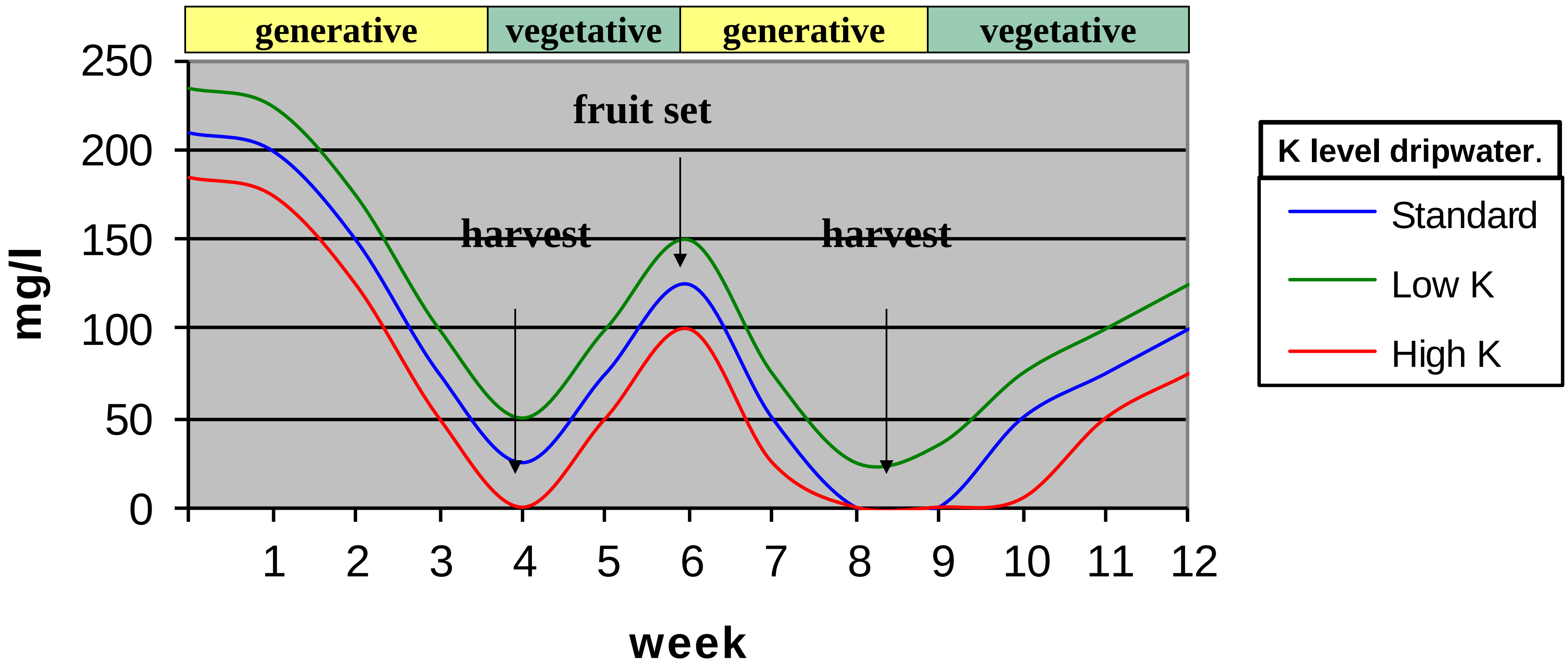


What happen when K is high

- K^+ oversupply does not show specific symptoms, other than reduced growth and harvest.
- K^+ oversupply reduce the uptake of Mg^{2+} en Ca^{2+}, causing deficiency symptoms characteristic for Calcium and Magnesium.

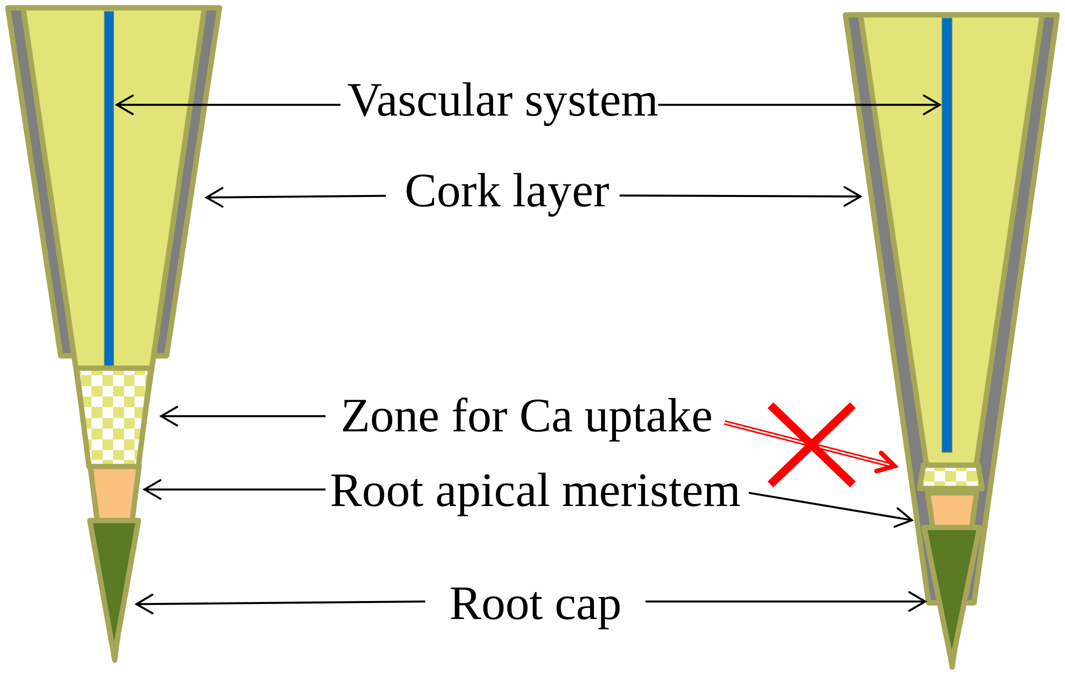
More K = more K uptake.
Risk of deficiency of Ca and Mg!

Calcium concentration in plant sap during growth.



Calcium uptake

Ca^{2+} uptake: Passive process



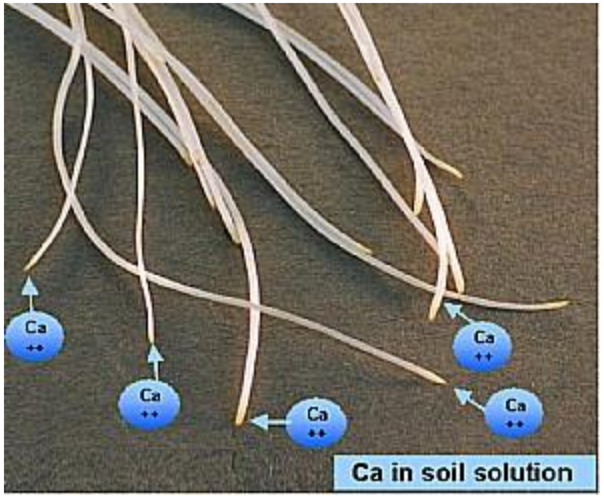
Vegetative growth
Root growth
Calcium uptake

Generative growth
No root growth
No Calcium uptake

Calcium uptake

During Vegetative growth:

1. Root growth.
2. Epidermis at the top of the root is young and thin.
3. Maximum Ca uptake possible.



During Generative growth:

1. Root growth limited.
2. Epidermis at the top became thicker (older).
3. Ca uptake not possible anymore.

Calcium in leafs and Fruit

- Calcium moves with the water flow to the leafs driven by evaporation of the leafs.
- Fruit don’t assimilate and receive very little Calcium

Higher concentration Calcium

Low concentration Calcium

Lowest Calcium level

Deficiency symptoms

Calcium deficiency:

- Deficiency especially in non evaporating and young plant parts.
- Plant strength of tissue and membranes is reduced. Development of weak spots and important material (fluids) can leak away.
- Meristem tissue can be affected.
- Quick ageing of plant (tissue, leaves etc.).
- Physiological problems:
  - Tip rot (tomato, paprika)
  - Glassiness (lettuce)
  - Heart rot (celery)
  - Pit (apple)

Summary

Conclusion based on Plant Sap experience:

- Too much Potassium disturb the Calcium uptake.
- Less Calcium uptake during generative growth.
- Too low Potassium gives smaller fruit size (K < 1 mmol/l in Rock wool).

And furthermore:

- Calcium uptake is passive activity.
- Calcium uptake is driven by evaporation of the leafs.
- Calcium moves with the water flow to the leafs.
- Calcium is not mobile.
- Fruit receives very little Calcium.
- The tip of the fruit has the lowest concentration of Calcium.

How you can help Calcium....

- Always take care about young / fresh root tips.
- Potassium not too high.
- Magnesium not too high.
- NH_4^+ not too high.

(Potassium, Magnesium, NH_4^+:) **Antagonism with Calcium.**

- Stimulates the evaporation for better Calcium uptake.
- Take care about available Calcium (Calcinit) in substrate.
- Keep Calcium available by pH control.

- **Use always a balanced nutrient solution!!**

Is Super FK the answer?

Super FK is a polyphosphate.

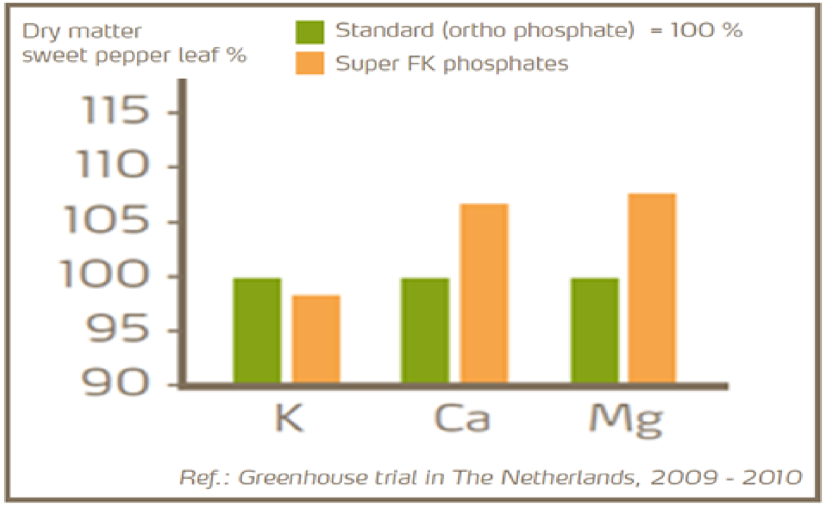
Strong effect on the growth.

More root development

More root tips

More Calcium uptake?

Next year new trials.



Questions?

The End