NORWEGIAN RECIRCULATION TRAINING DAY

January 16th 2020

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NORWEGIAN RECIRCULATION TRAINING DAY

- The Scandinavian experience
- Disinfection systems
- Crazy roots
- Raw water quality

PAUSE

- Uptake of nutrients
- Recipe changes
- Mixers and stock tanks

THE SCANDINAVIAN EXPERIENCE

	NL	UK	DK	SV	N	SF
Tomato (ha) 2008	1380	175	41	45	39	120
% recirculation	100	15	83	30	25	2

- Growers in DK were given no lead time to start recirculation
- Local authorities did not demand recirculation; they simply increased the fee for ”dumping” to very high levels in 2005!
- All the large nurseries in DK, SV and N started to recirculate
- Some other smaller nurseries invested due to rising fertilizer prices
  - Breakeven area was ca 1,5 ha
- From 2020 nurseries in DK, using certain pesticides, must have closed systems! Does not apply yet to fertilizers

THE SCANDINAVIAN EXPERIENCE:

Collection capacities

	drain tank (m^3/ha)	disinfection method	clean tank (m^3/ha)	premix (m^3)	rain collect (m^3/ha)
AP	55	heat	20	none	3100
NMR	0	zeolite filter	20	24+heat	2250
ØST	50	UV 250	50	none	3000
AP TR	43	ECA	in mixer	2 x 400	7400
KWM	50	UV	50	none	none

Make sure that the system has enough capacity to take into account sunny / dull weather changes and sterilizer down time. Red = too small

APTR and NMR ran out of rainwater in the dry summer of 2018!!

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DISINFECTION SYSTEMS

- Heat (AP Bellinge)
- UV (Østervang + KWM)
- Bio filter / slow sand filtration (NMR)
- ECA (electrochemical activation) (AP TR)
- Ozone
- Ultra filtration

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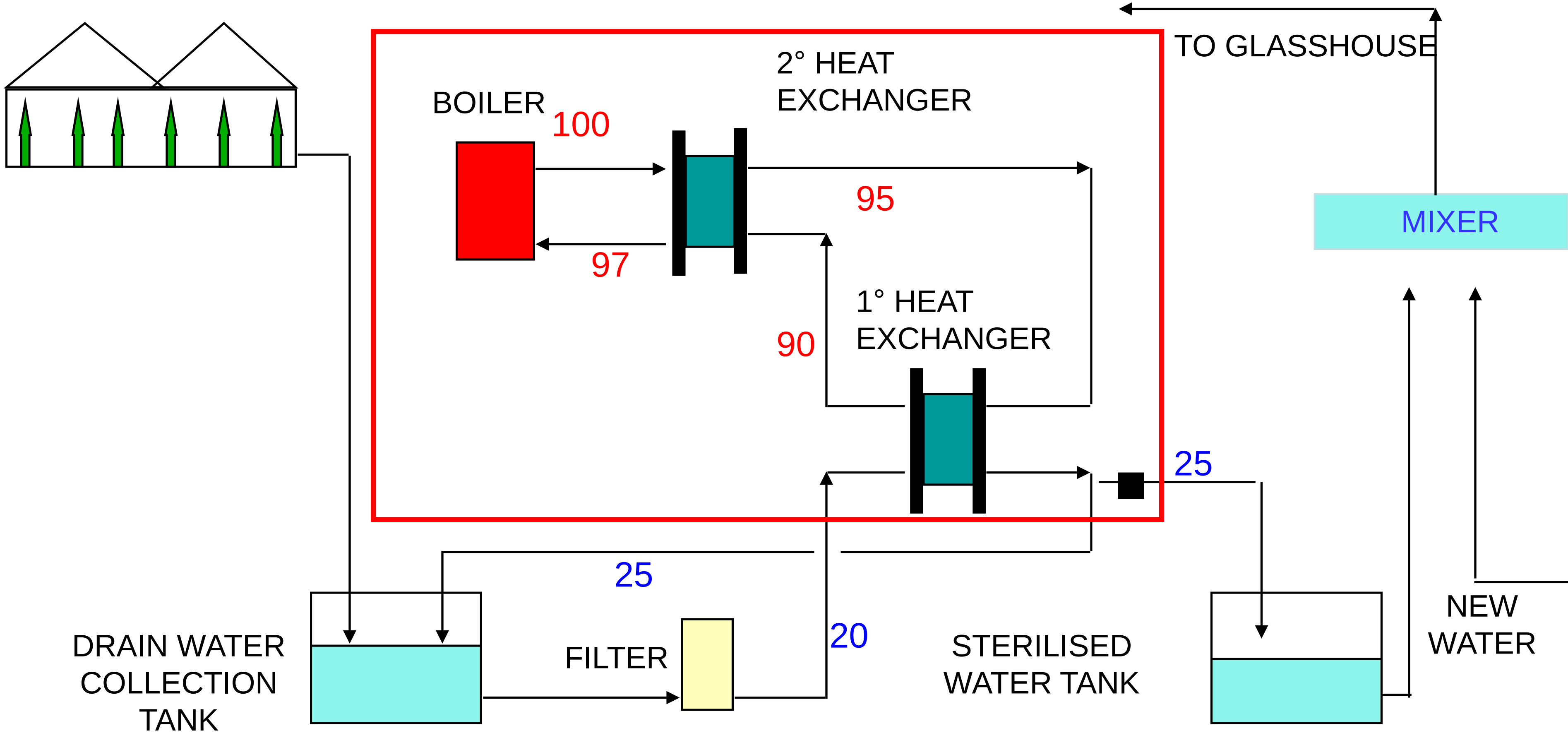
DISINFECTION OF DRAIN WATER



In this example heat treatment is used, but in principal different equipment can be used inside the red box

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DRAIN WATER STERILIZATION
HEAT

Method:	95°C x 30 seconds
Efficiency:	Fungi, bacteria and viruses
Capacity:	1.6 - 16 m^3 / hour
Problems:	Fertilizer salts (calcium sulphate) coating heat exchanger plates requires acid cleaning
Pre-treatment:	Filter (0.1mm)

DRAIN WATER STERILIZATION:
HEAT 1

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DRAIN WATER STERILIZATION:
HEAT 2: acid cleaning of exchanger plates

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DRAIN WATER STERILIZATION: UV

Method:	250 nm wavelength x 100 mJ/cm^2
	or x 250 mJ/cm^2
Efficiency:	100 mJ/cm^2: fungi, bacteria, but not virus
	250 mJ/cm^2 needed for elimination of viruses
Capacity:	1,6 - 16 m^3/ hr
Problems:	Fe chelates damaged – need to add extra separately
	If optical density is a problem, a mixture of drain and fresh water is used to maximise effect
Pre-treatment:	Filter (0.04 mm)

The glass tubes are cleaned automatically if the light transmission is not enough

DRAIN WATER STERILIZATION: UV

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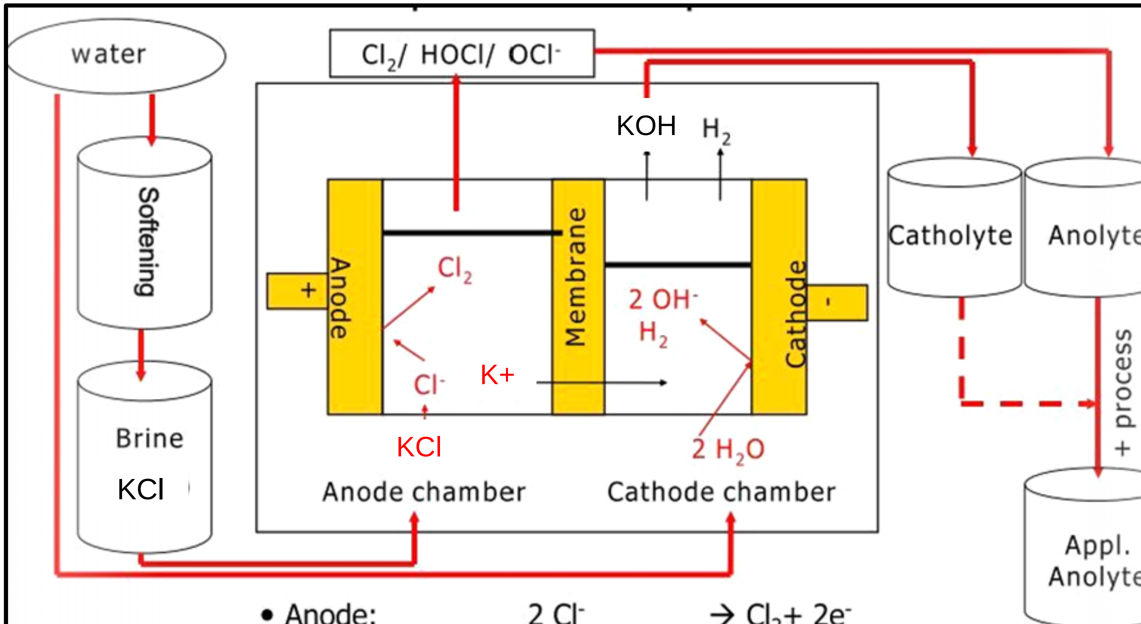
ELECTRO CHEMICAL ACTIVATION

- 2 electrodes (anode + cathode) generate a solution which contains free chlorine, as hypochlorite (ClO^-), and hypochlorous acid ($HClO$) in the anode chamber
- The free radicals are acting as powerful oxidizing agents.
- These are generated from potassium chloride, which must be laboratory grade. Do not use sodium chloride!
- No extra clean water storage is needed – the process takes place as part of the fertilizer mixer
- There is a potential problem with this system: the generation of chlorate (ClO_3^-), which can be taken up by plants. Edible produce has a Maximum Residue Limit of 0,01mg/kg

ELECTRO CHEMICAL ACTIVATION

SCHEMATIC BUILD OF AN ECA PLANT



- Anode: $2\,Cl^- \rightarrow Cl_2 + 2e^-$
- Cathode: $2\,H_2O + 2e^- \rightarrow H_2 + 2\,OH^-$
- Cathode chamber: $2K^+ + 2OH^- \rightarrow 2\,KOH$
- Anode chamber: $Cl_2 + H_2O \rightarrow HOCl + HCl$
- <u>further reaction products of the Anode side:</u>
  → hydrogen peroxide, active oxygen forms, ozone

VLB Berlin, Ahrens

Bangkok 20

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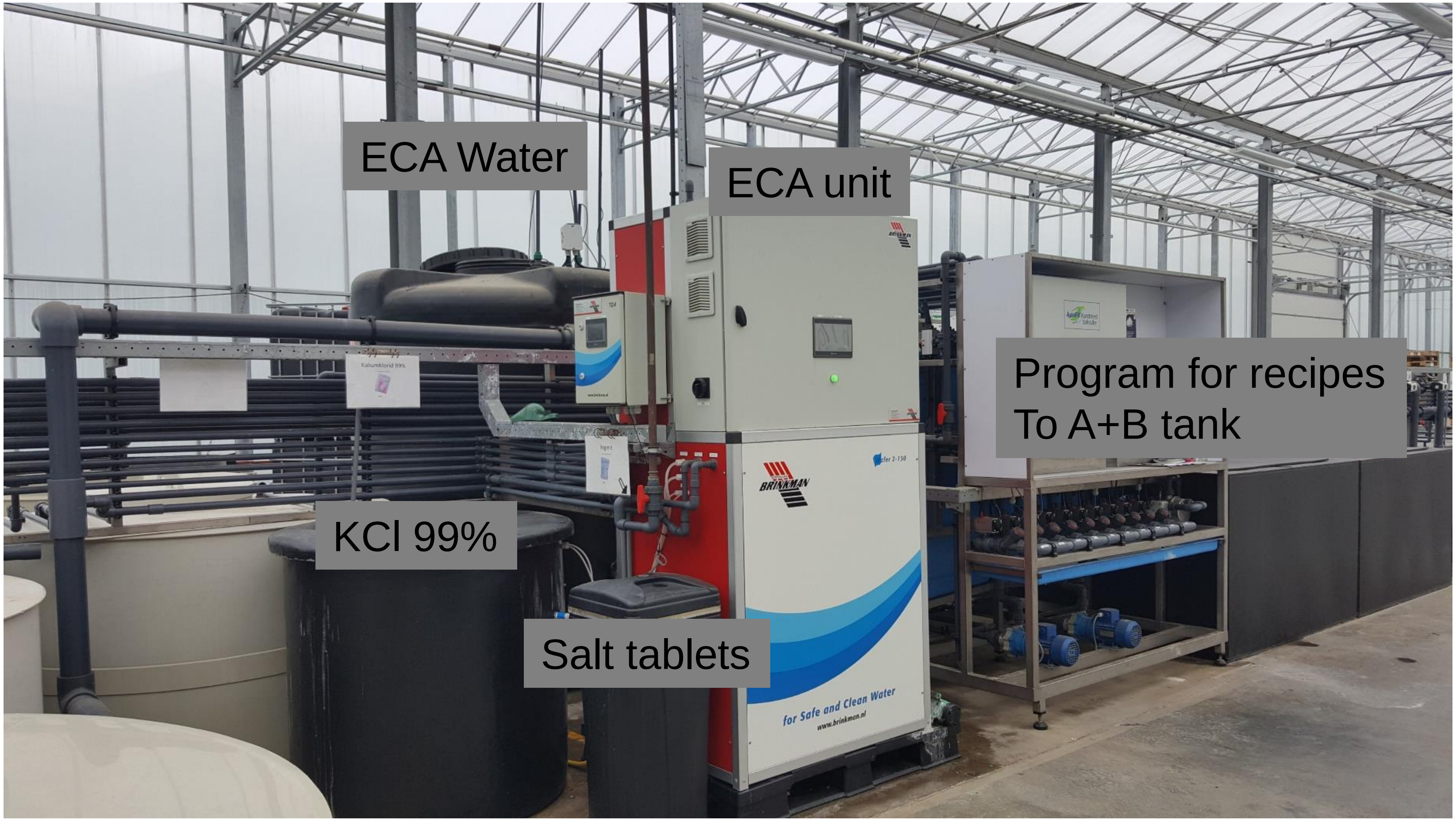
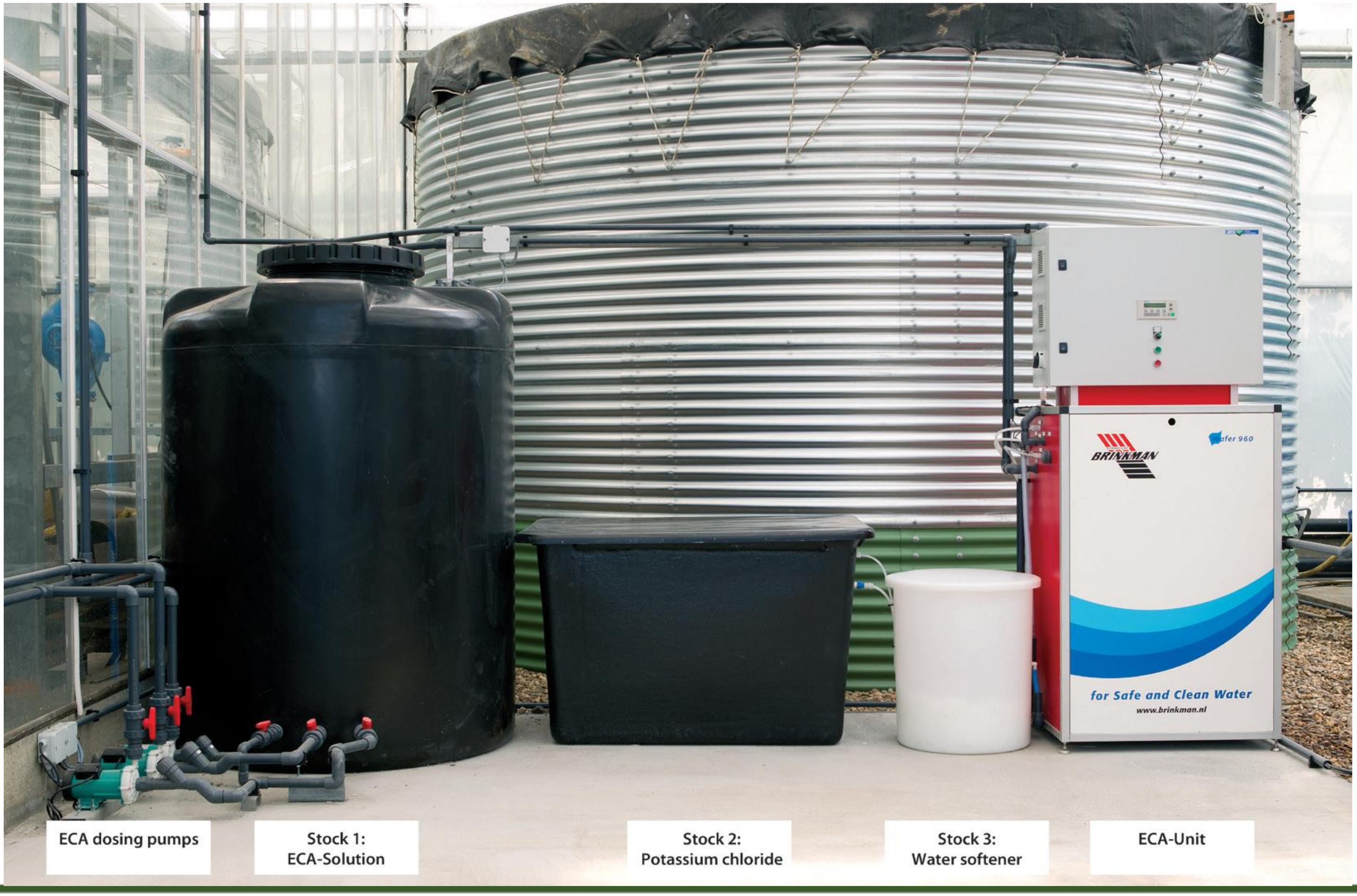
Electro Chemical Activation



Electro Chemical Activation



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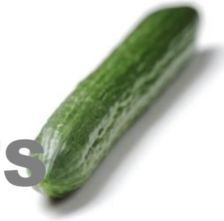
SO WHICH STERILIZATION TECHNIQUE?

- Each system has proved successful
- UV requires a high optical transmission. Therefore not so suitable if peat or coir (kokos) are the media as they generate some colour
- Biofilters require “faith”. You cannot measure their effect hour for hour
- Heat is a good choice, especially if you are producing CO_2 without a buffer tank
- My personal choice is between heat and ECA, provided there is not a chlorate issue
- If I am pushed, then heat would be my preferred choice:
  - It is easy to measure temperature and time: 95 C x 30 seconds – everything killed

CRAZY ROOTS /ROOT MAT

CRAZY ROOTS: SOME GENERAL POINTS



- Crazy roots are caused by plasmid DNA located in a bacterium (*Rhizobium radiobacter*).
- When this DNA enters the plant root, it genetically modifies the plant root cells
- Both tomatoes and cucumbers can be affected
- The result is excessive vegetative growth in both roots and tops
- This can lead to 15% yield loss
- It is thought that it is <u>not</u> seed transmitted, but plant raisers have often been cited as a primary source
- Visual symptoms, on pre-infected plants, can take a long time to appear (8 – 16 weeks)
- There is no cure, but there are treatments that can reduce infection and spread

CRAZY ROOTS: DISINFECTION

- Only 3 things to remember:
  - hygiene
  - hygiene
  - and hygiene!
- New growing media every crop. Infected re-used slabs appear to pose a greater threat. Some sources claim that the problem is less on kokos compared to rockwool
- Effective crop turnaround disinfection protocol, with special attention to the irrigation system from the mixer to the dripper:
  - chlorine dioxide (Clorius 2) at 25 ppm. Best?
  - 1 - 2% sodium hypochlorite
  - hydrogen peroxide based products are less effective
  - treatment 1/week, compared to only once, seems more effective

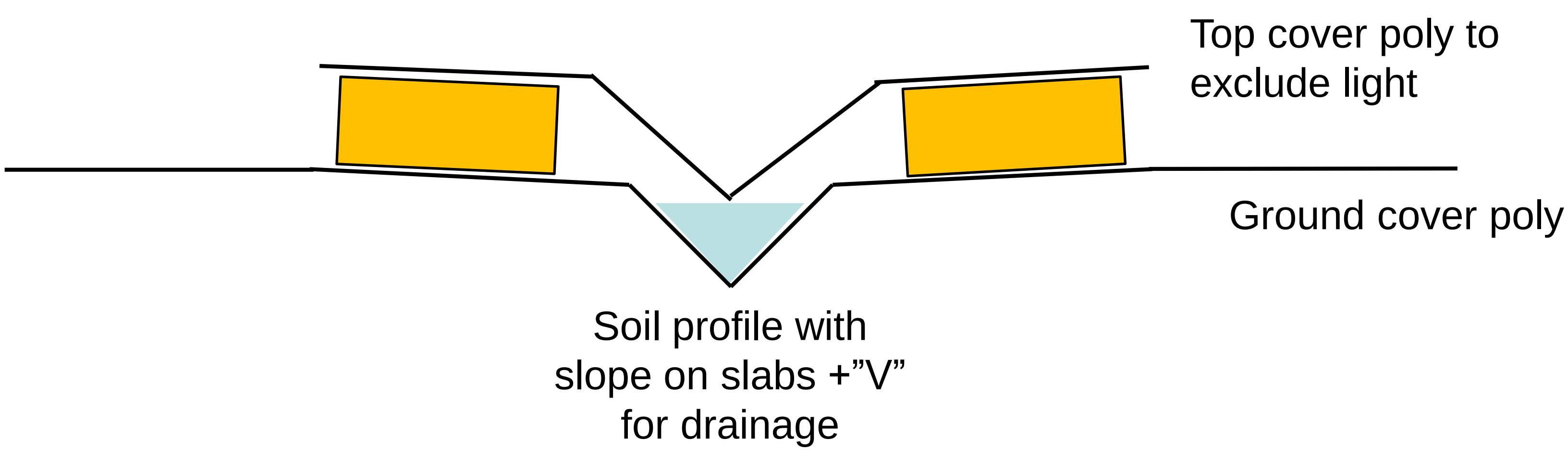
CRAZY ROOTS: CROP TREATMENTS

Approach requires combined treatment approach:

- Propagation treatments:
  - Biochar (Carbon Gold) 5 gram / block
  - *Trichoderma harzanium* (Koppert Trianum P) 0,15 gram/m^2
- Planting treatments:
  - Biochar (Carbon Gold) 55 gram under each block
- Post planting:
  - chlorine dioxide (Clorius 2) at ca. 3 ppm at the mixer to achieve 0,2 ppm (non-phytotoxic) at the dripper
  - hydrogen peroxide to achieve 10 ppm at the dripper
- However grower practical experience variable

DO I NEED HANGING GUTTERS?

- The popularity of hanging gutters was mainly due to:
  - Increasing labour efficiency
  - Improved air circulation
  - Improved root zone hygiene
- However recirculation of the drainage water can be achieved by soil or polystyrene profiling:



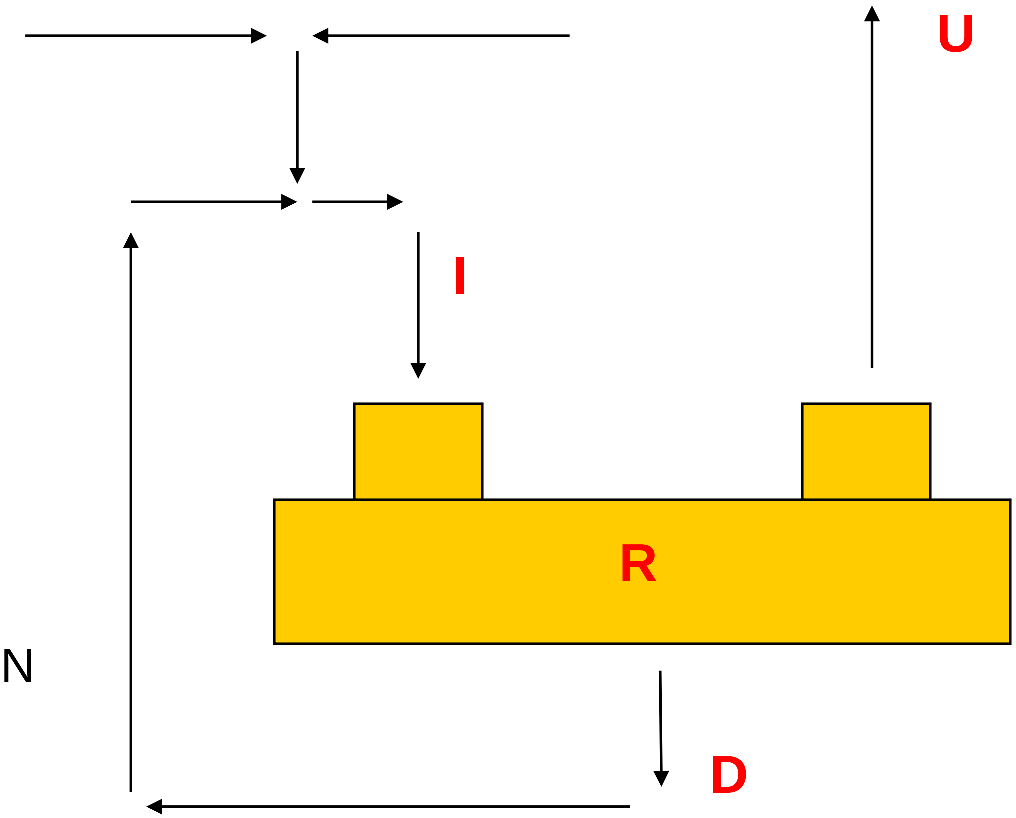
CLOSED SYSTEM BASIC PRINCIPLES

R = ROOTZONE

I = INPUT

U = UPTAKE

D = DRAIN



I > U = ACCUMULATION

I < U = DEPLETION

RAW WATER QUALITY

- There are elements that you have to be more aware of when switching from an open to a closed system:

– Na and Cl	Raw water and fertilizers
– Zn	Galvanised gutters
– Cu	Brass pipe fittings
– HCO_3	Water source and disinfection equipment.
– Ca, Mg, S	Water source, but usually adjusted in the recipe program so that targets are met

BOREHOLE WATER QUALITY:
AP, NMR, AP TR, ØSTERVANG, WIIG, WS

GROWER	EC	N	K	Ca	Mg	B	Zn	Na	Cl	S	HCO_3
AP	0,52	0	3	90	9	0	0,05	17	25	19	265
NMR	0,72	0	6	90	**24**	**0,18**	0,20	**36**	**72**	0	415
AP TR	0,77	5	5	**130**	10	0,07	0	**25**	35	20	420
ØSTERVANG	0,71	0	2	110	16	0,03	0	19	36	23	363
KW	0,15	0	0	21	1	0	0	**4**	7	1	68
WS IOW NS	0,28	2	3	37	7	0	**0,52**	17	27	17	83
WS IOW MLN	0,38	0	3	53	5	0	0	**22**	41	10	151
WS IOW LEN	0,38	0	2	64	5	0	0	**23**	36	13	154
WS KENT TOP	0,68	10	0	100	5	0	0	**25**	21	10	371

TOO HIGH **BORDERLINE**

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BICARBONATE

- Rainwater and Norwegian borehole water have bicarbonate levels in the range 20 – 60 ppm
- Acid cleaning of heat exchanger plates and UV glass tubes can reduce bicarbonate in the cleaned drain water to zero
- The bicarbonate level, before pH correction on the mixer, should be 40 ppm
- This means we have to add bicarbonate at the mixer, usually potassium bicarbonate. Ideally this should have it’s own tank – it is not compatible with most fertilizers
- If the pH in the rootzone falls too low, a proportion of the normal calcium nitrate can be substituted with the pure form that contains zero ammonium

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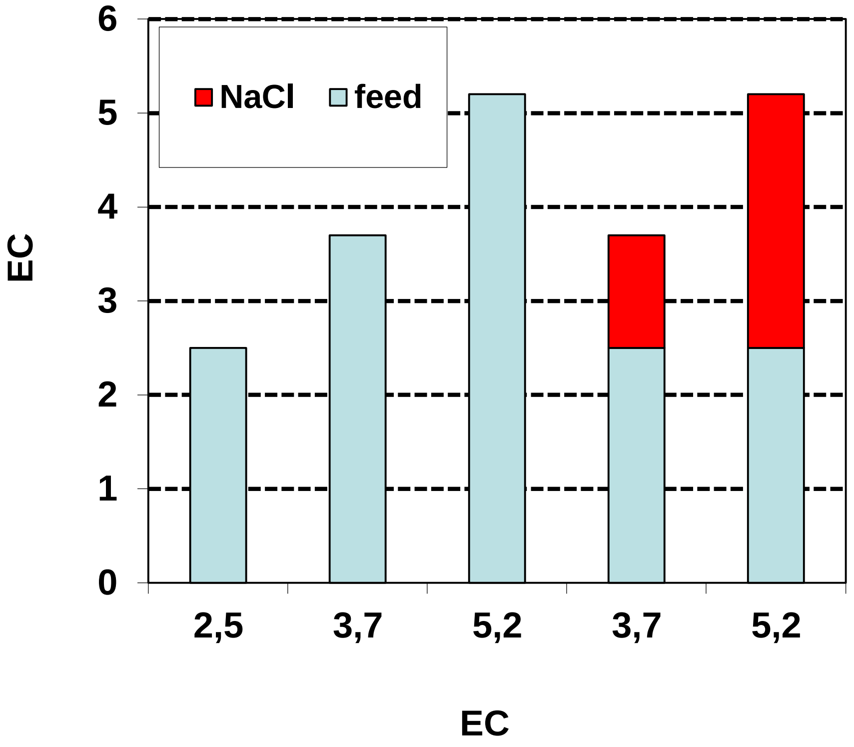
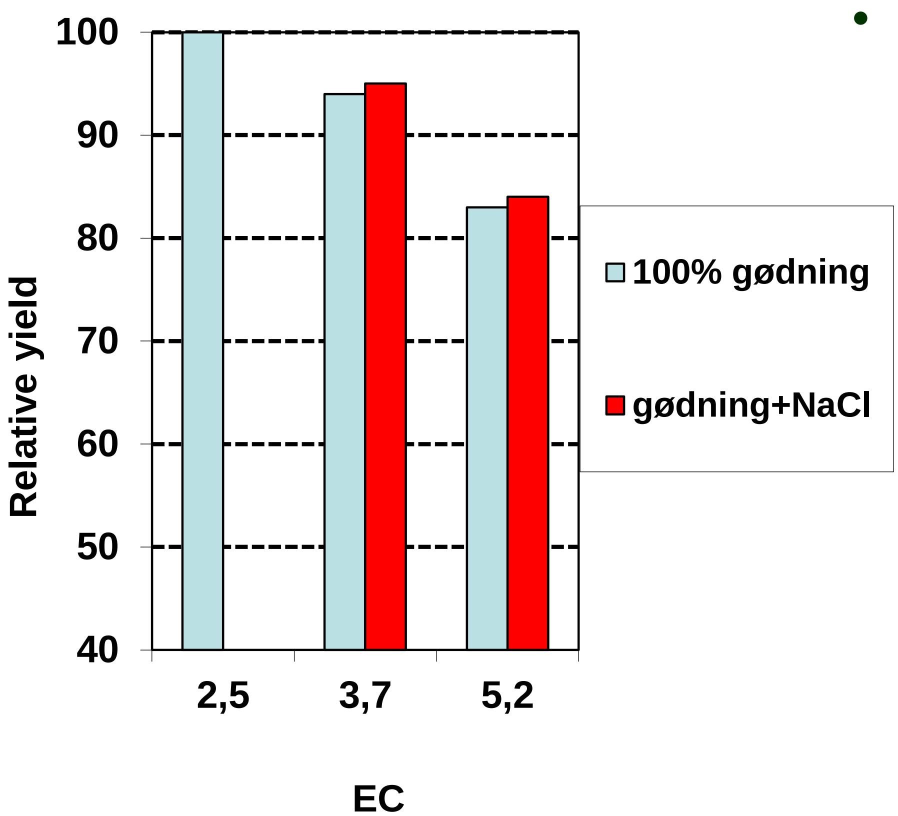
SODIUM and CHLORIDE

- Naaldwijk conducted experiments where they replaced normal nutrients with sodium chloride at E.Cs over 2,5 to study whether crop effects were due Na, Cl or E.C. The extra Na for treatments 4+5 are ca. 80 and 180 ppm



EFFECT OF SODIUM CHLORIDE ON TOMATO YIELD



- Yield reduction is an E.C effect and not a direct effect of Na or Cl

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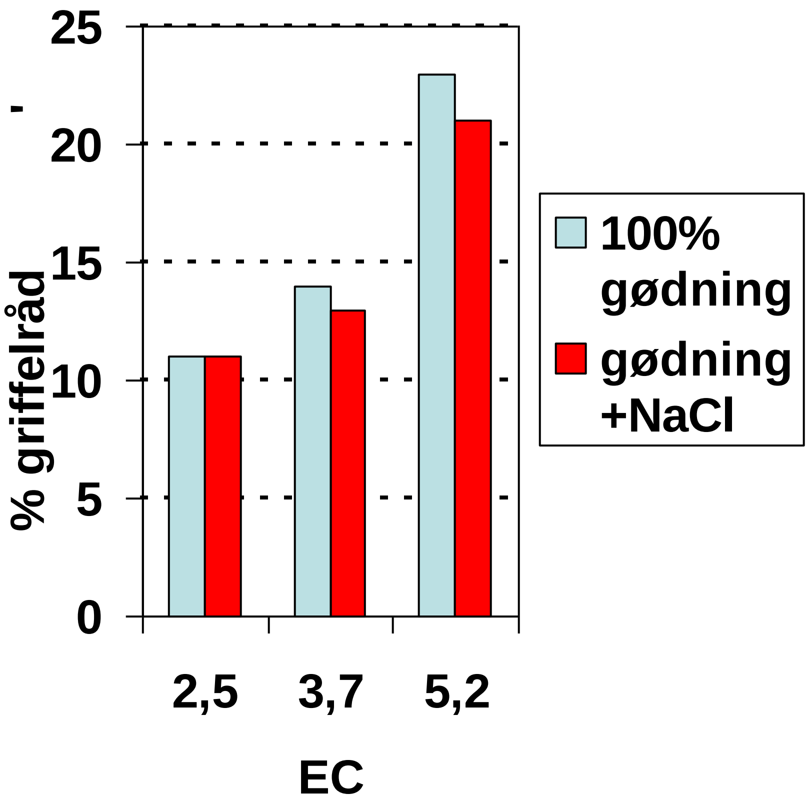
EFFECT OF SODIUM CHLORIDE ON BLOSSOM END ROT IN TOMATO



- Increase in blossom end rot is an E.C effect and not a direct effect of Na or Cl

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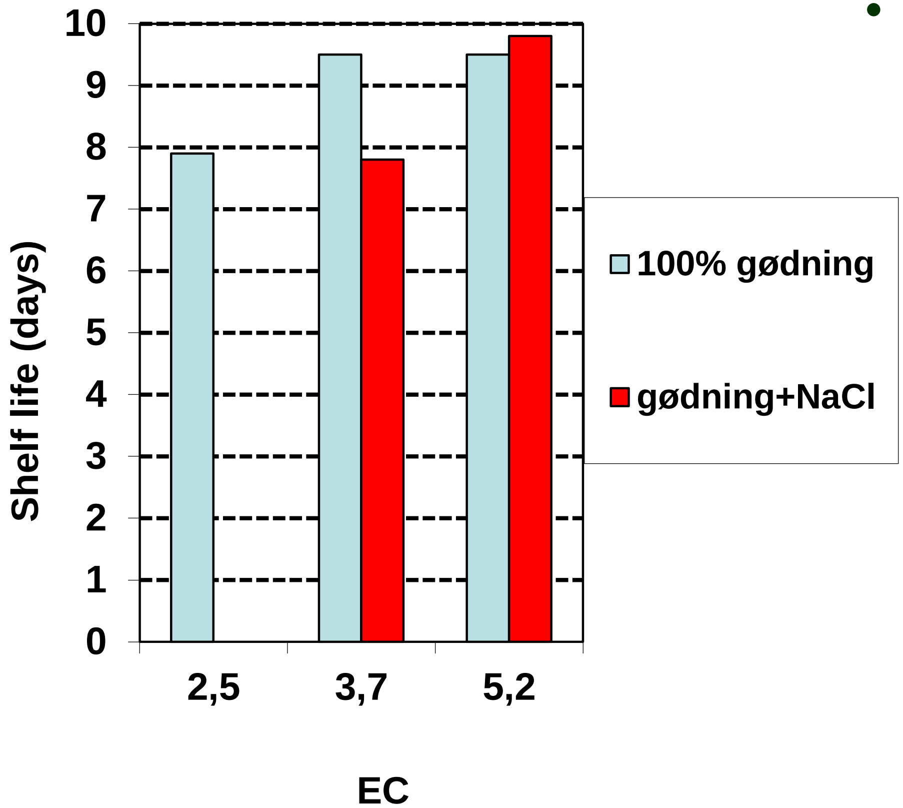
EFFECT OF SODIUM CHLORIDE ON TOMATO SHELF LIFE



- Extension of shelf life is an E.C effect and not a direct effect of Na or Cl

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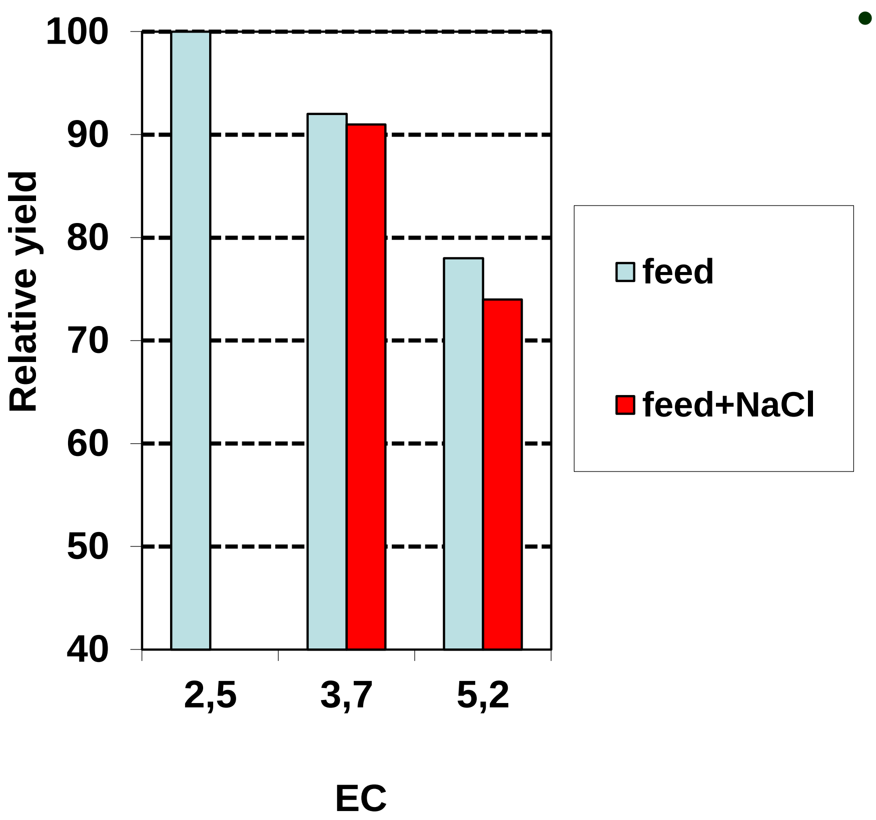
EFFECT OF SODIUM CHLORIDE ON CUCUMBER YIELD



- Yield reduction is mainly an E.C effect, but there is an extra effect of Na and Cl

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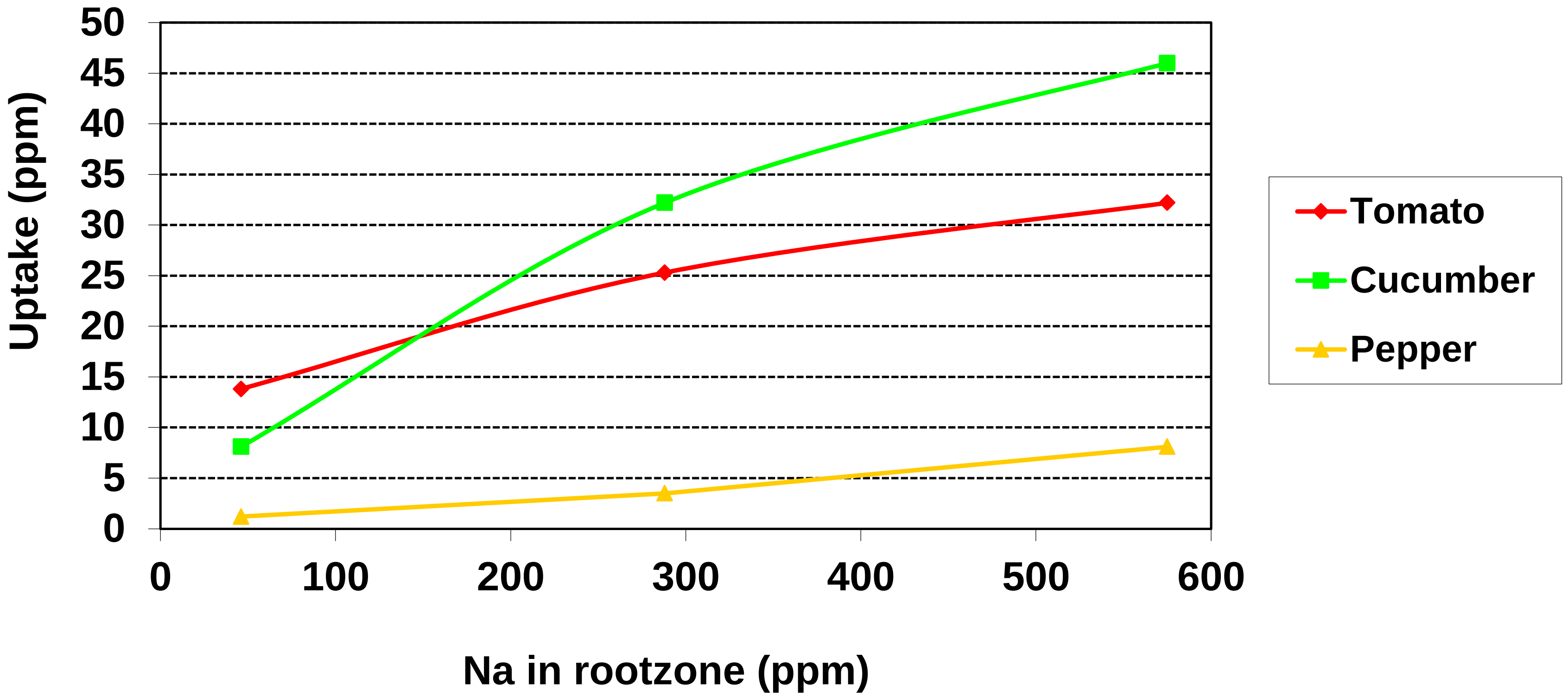
SODIUM AND CHLORIDE
UPTAKE OF SODIUM



Tomatoes and peppers are good at saying no to sodium

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SODIUM AND CHLORIDE
MAXIMUM CONCENTRATIONS AND MAXIMUM UPTAKE

Crop	Max root concentration (ppm)		Uptake	
	Na	Cl	Na	Cl
Tomato	230	530	23	43
Cucumber	185	355	28	71
Pepper (veg)	185	425	18	36
Pepper (gen)	185	425	7	32
Lettuce	185	530	35	71
Chrysanthemum	140	285	7	32
Rose	140	285	7	36
Gerbera	140	355	9	53

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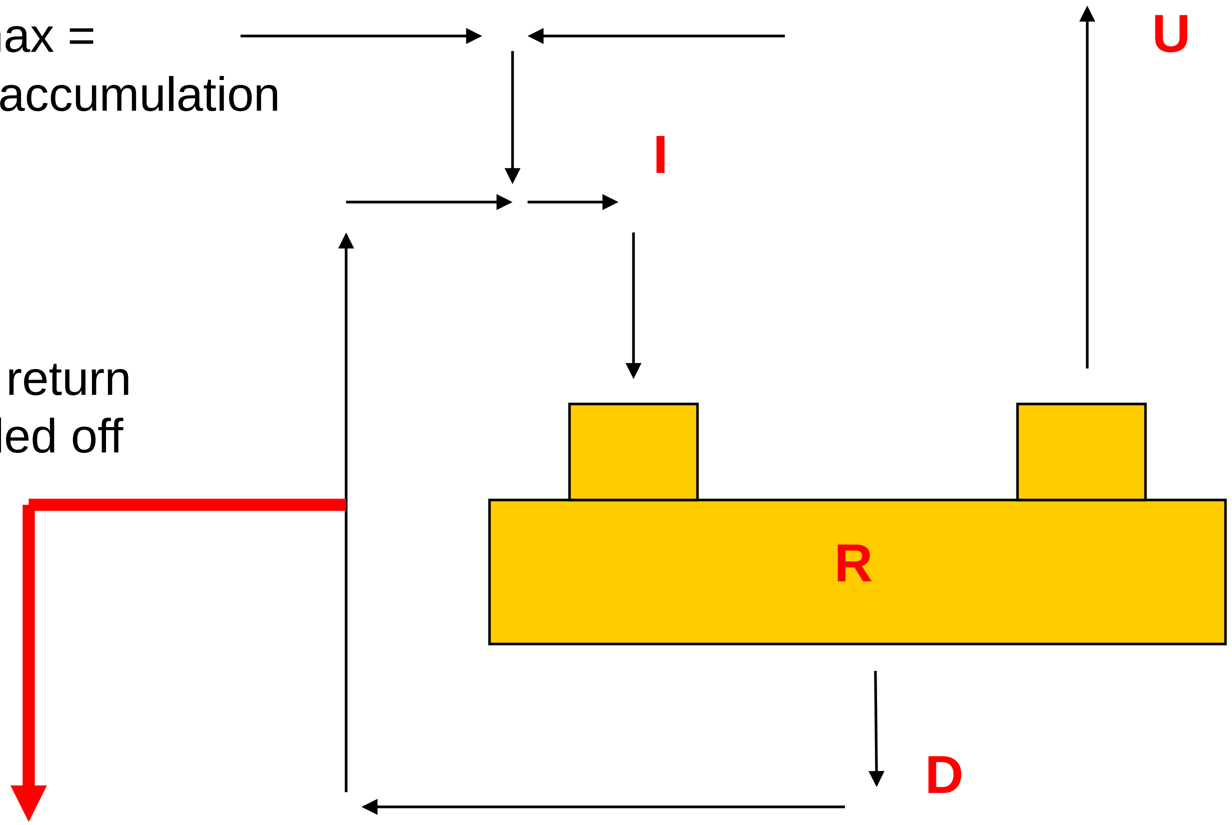
NUTRIENT ACCUMULATION IN DRAIN

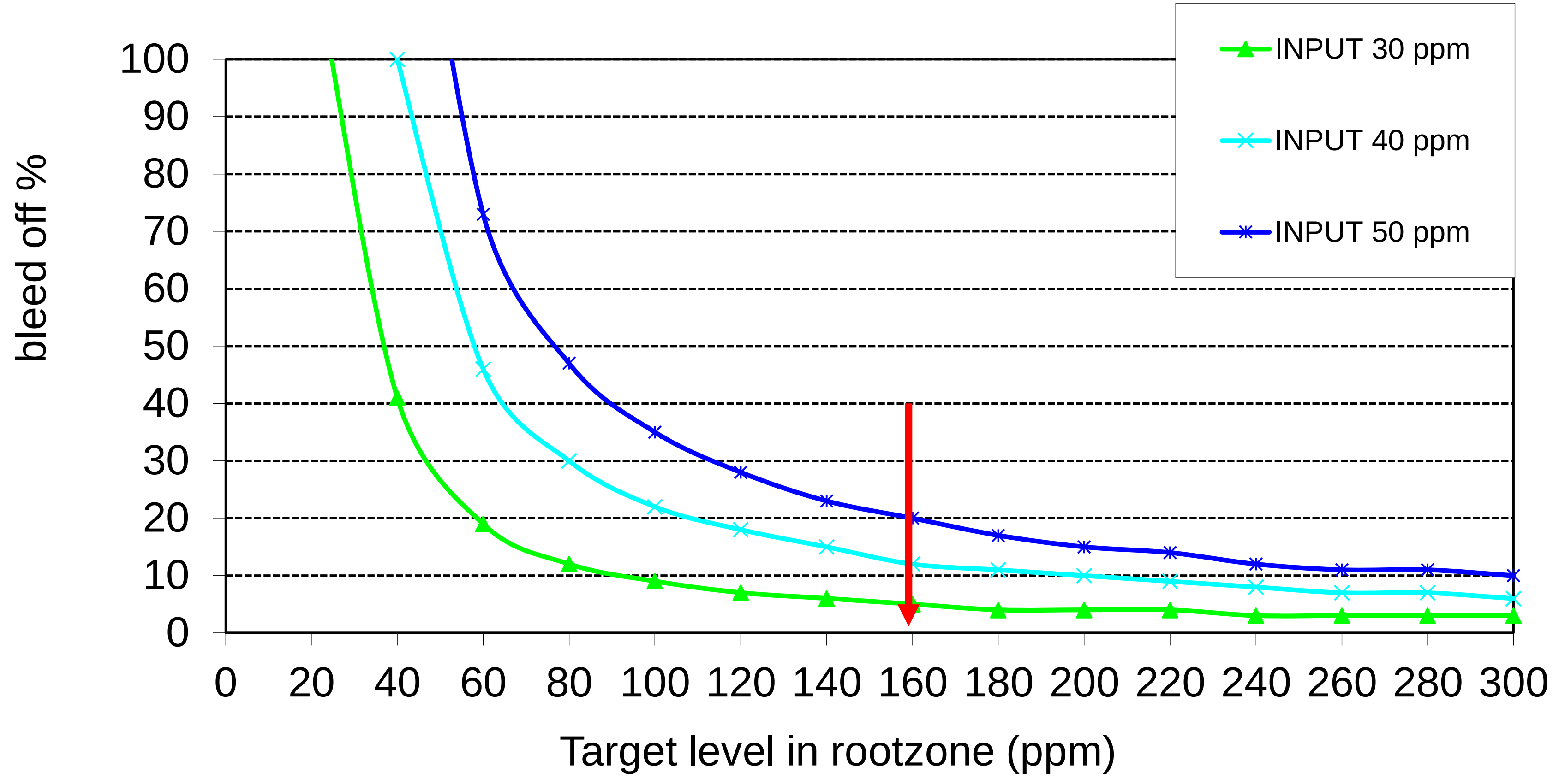
If **I** > **U** max = accumulation

→ % of return water bled off



SODIUM AND CHLORIDE

CALCULATION OF BLEED %: SODIUM IN TOMATO



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SODIUM LEVELS

- For most crops we are looking for less than 23 ppm Na in the drip
- Most of the Na in the closed system normally comes from the water source(s), but there also small amounts in some of the fertilizers. How much depends on fertilizer type and quality:

	K	Ca	Na	Cl
Potassium chloride	100		3	96
Calcium chloride		100	2	178
Potassium nitrate (Haifa Multi K Reci)	200		0,08	
Potassium nitrate (Haifa Multi K pHast)	200		0,8	
Potassium nitrate (NOP HT Topsoe)	200		1,6	
Potassium nitrate (Krista K Yara)	200		3,2	

- To take into account the amount in the fertilizer, the incoming drain Na must not exceed 19 ppm

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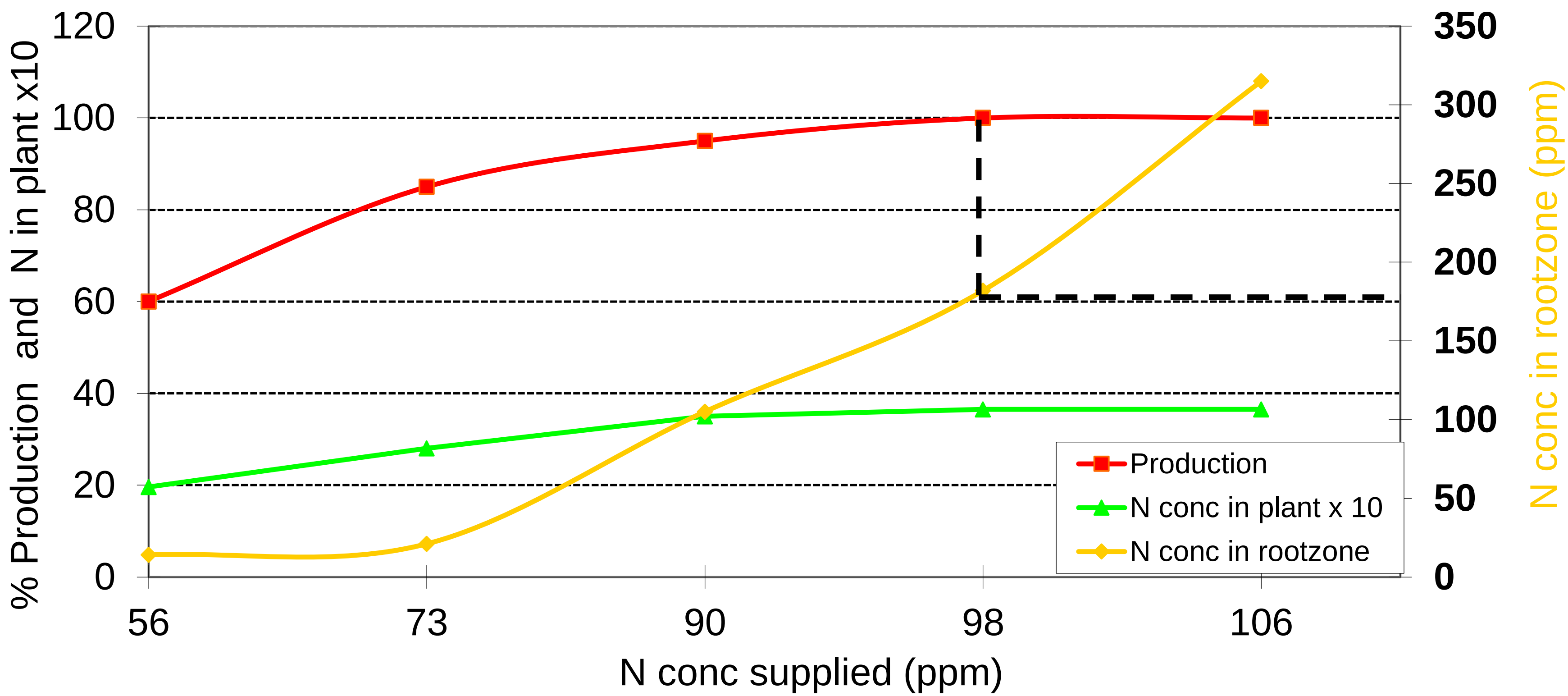
UPTAKE OF NUTRIENTS

- Continuous process
- Quantity is determined by growth rate
- Concentration in the plant is determined by transpiration
- The ratios between the nutrients (mainly K, Ca and Mg) is determined by the changing balance between fruit load and vegetative growth
- This is especially important in crops with a maximum fruit load (tomato) and fluctuating load (pepper). High wire lit cucumber present less of a problem – ”fixed” fruit load

UPTAKE OF NUTRIENTS IN CLOSED SYSTEMS: NITROGEN



There is still plenty of potential to reduce nitrogen in our recipes and substitute with sulphur and chloride, especially in tomato

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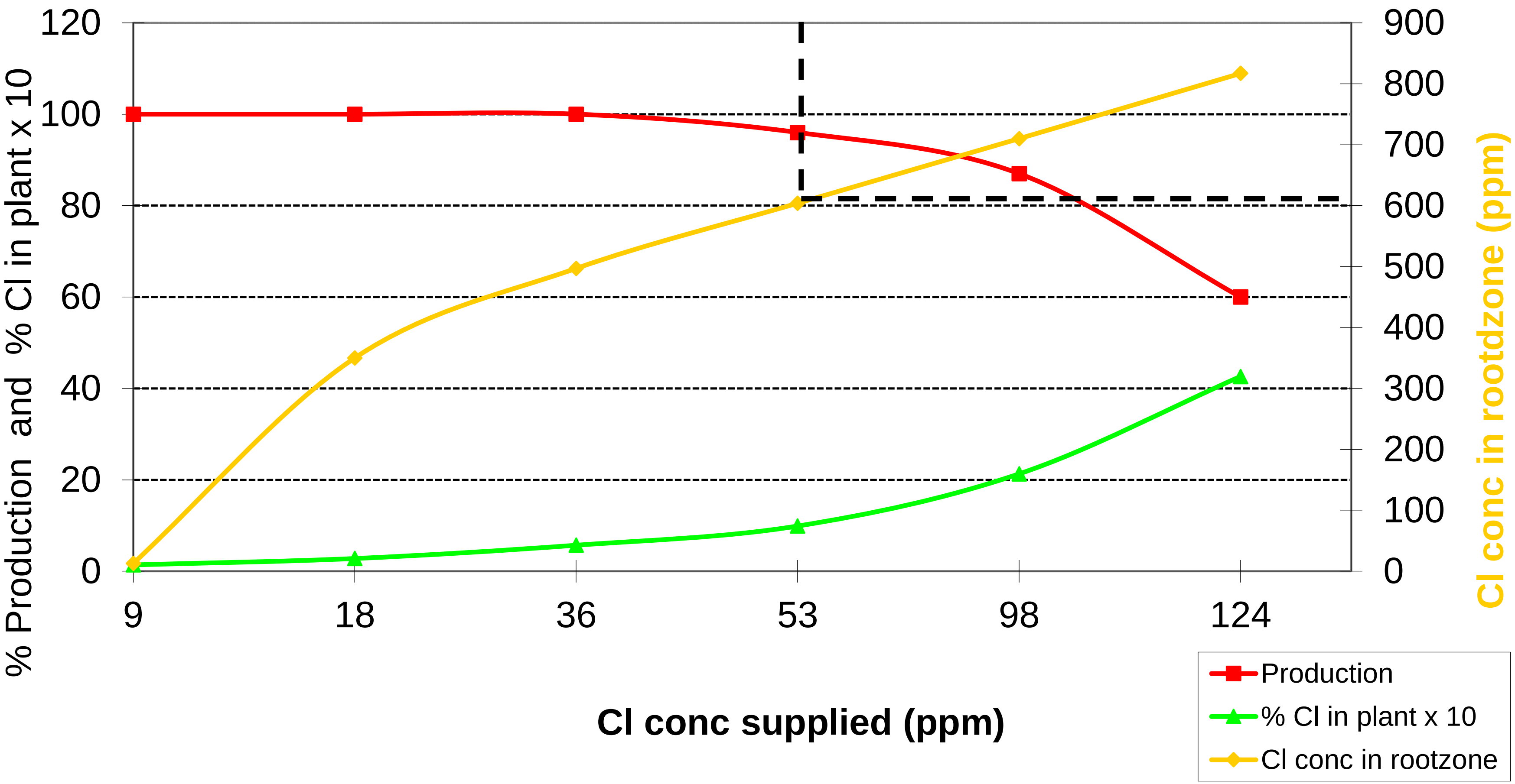
UPTAKE OF NUTRIENTS IN CLOSED SYSTEMS: CHLORIDE



Effect on yield, what comes first Cl ppm or E.C?

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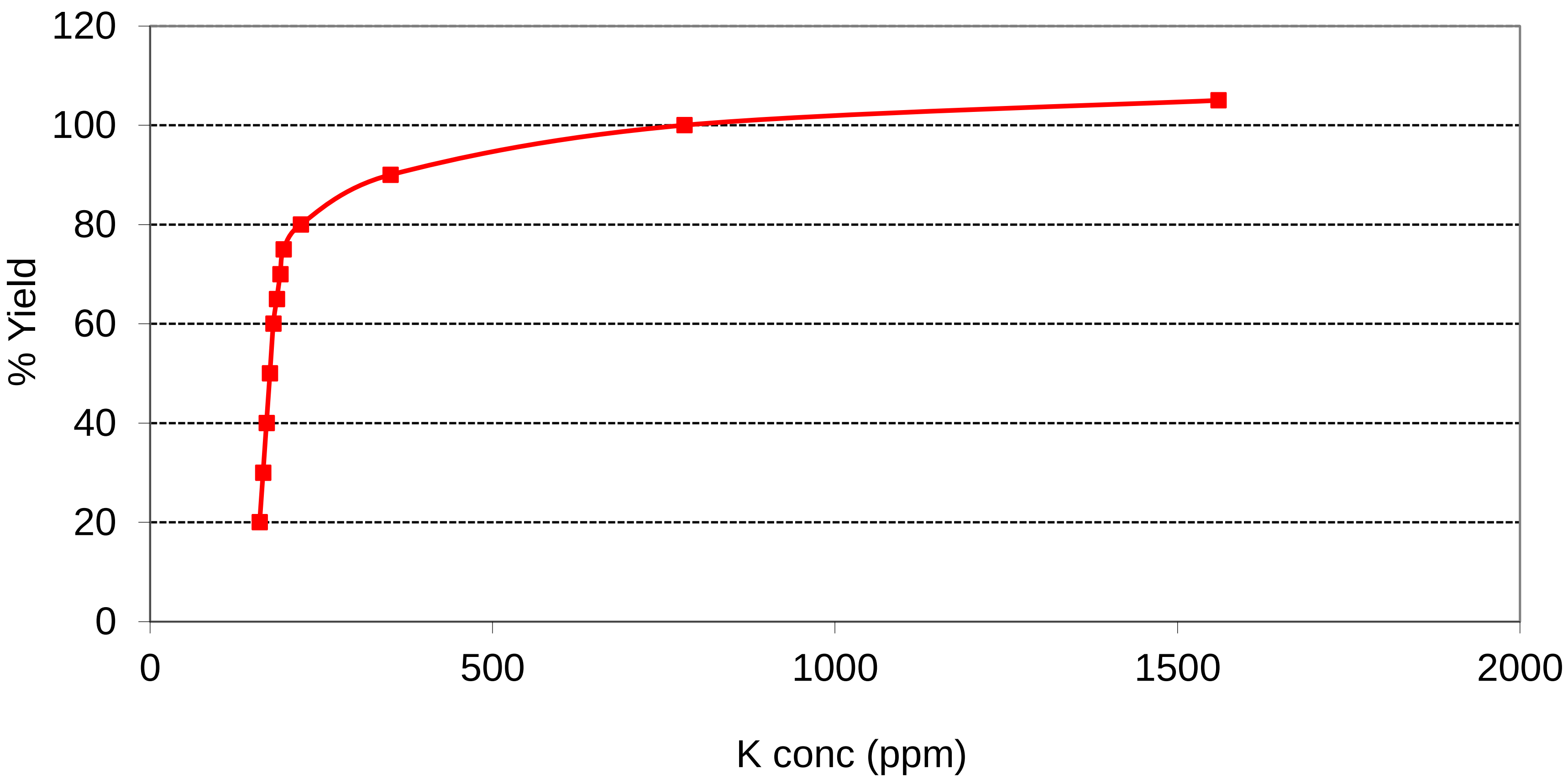
UPTAKE OF NUTRIENTS IN CLOSED SYSTEMS: POTASSIUM



Maintaining K concentration in closed systems is critical

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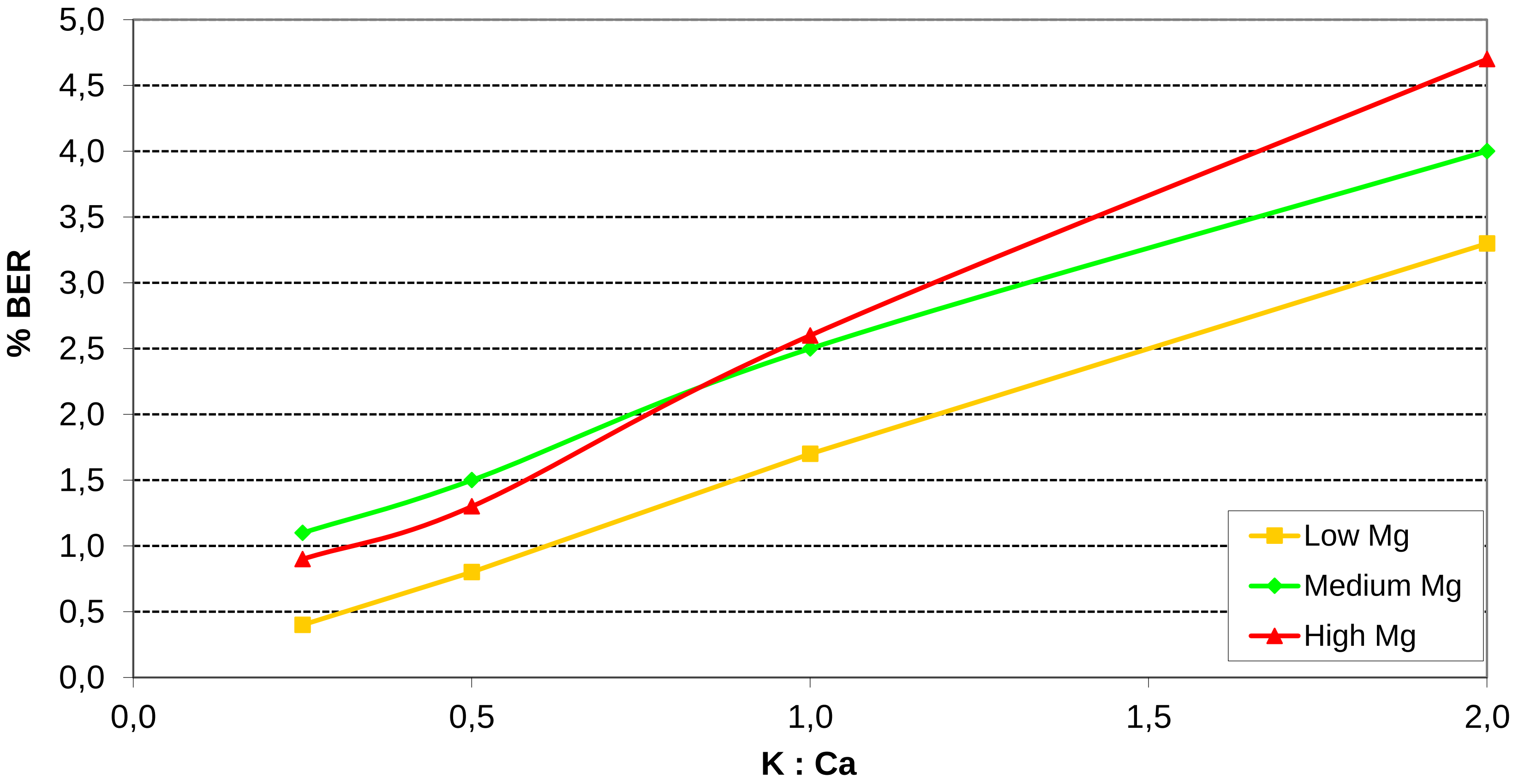
POTASSIUM AND FRUIT QUALITY (1)
BLOSSOM END ROT



Higher Mg levels will compete more with Ca uptake

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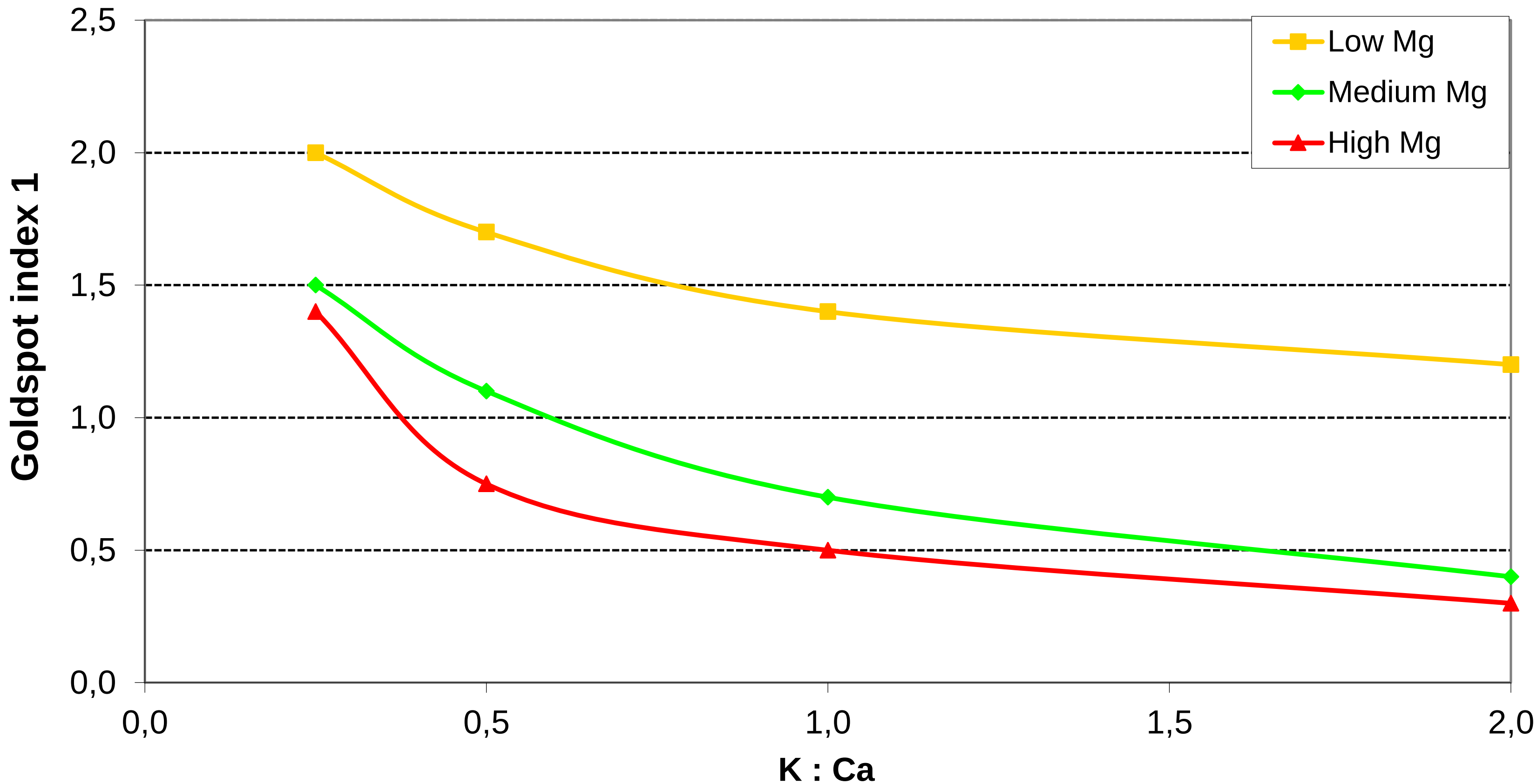
POTASSIUM AND FRUIT QUALITY (3) GOLDSPOTS



Normally, but depending on the varieties sensitivity, we are aiming for K : Ca of 1,0 in the rootzone. Again higher Mg is competing with Ca uptake

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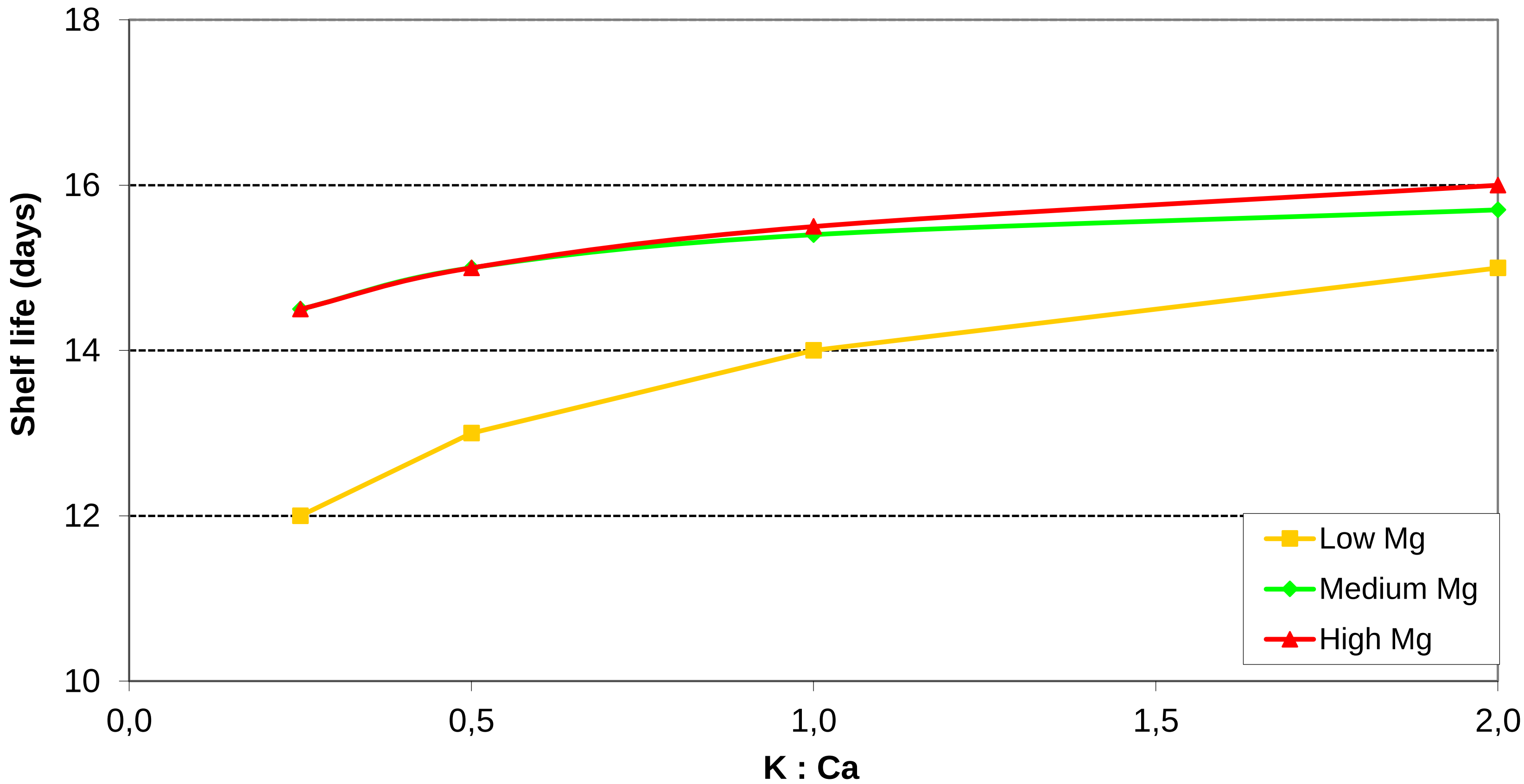
POTASSIUM AND FRUIT QUALITY: SHELF LIFE



As long as Mg concentration is sufficient, K : Ca of 1 OK

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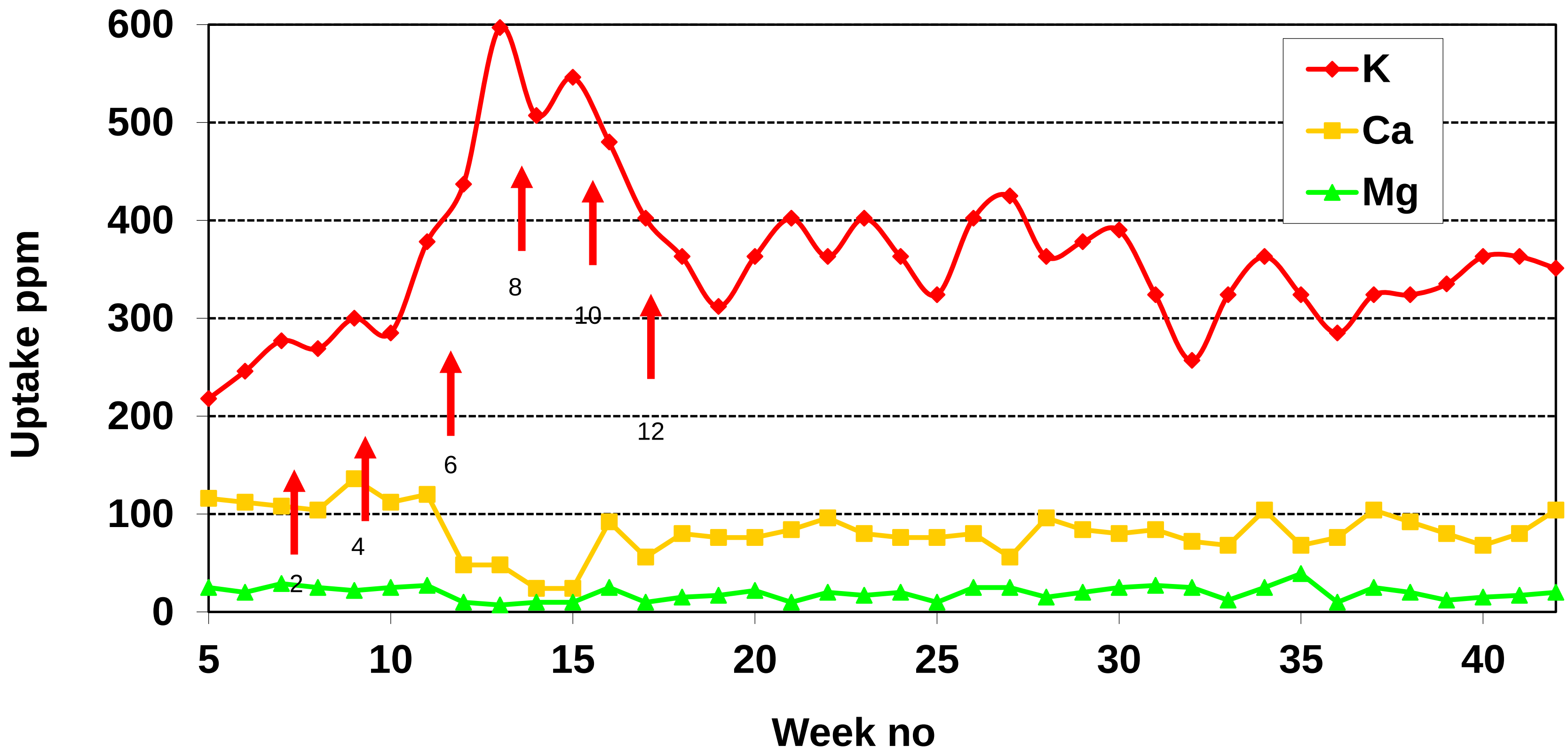
POTASSIUM, CALCIUM & MAGNESIUM UPTAKE IN TOMATOES



As fruit load increases, so does potassium uptake
At the same time calcium and magnesium uptake decrease due to uptake antagonisms

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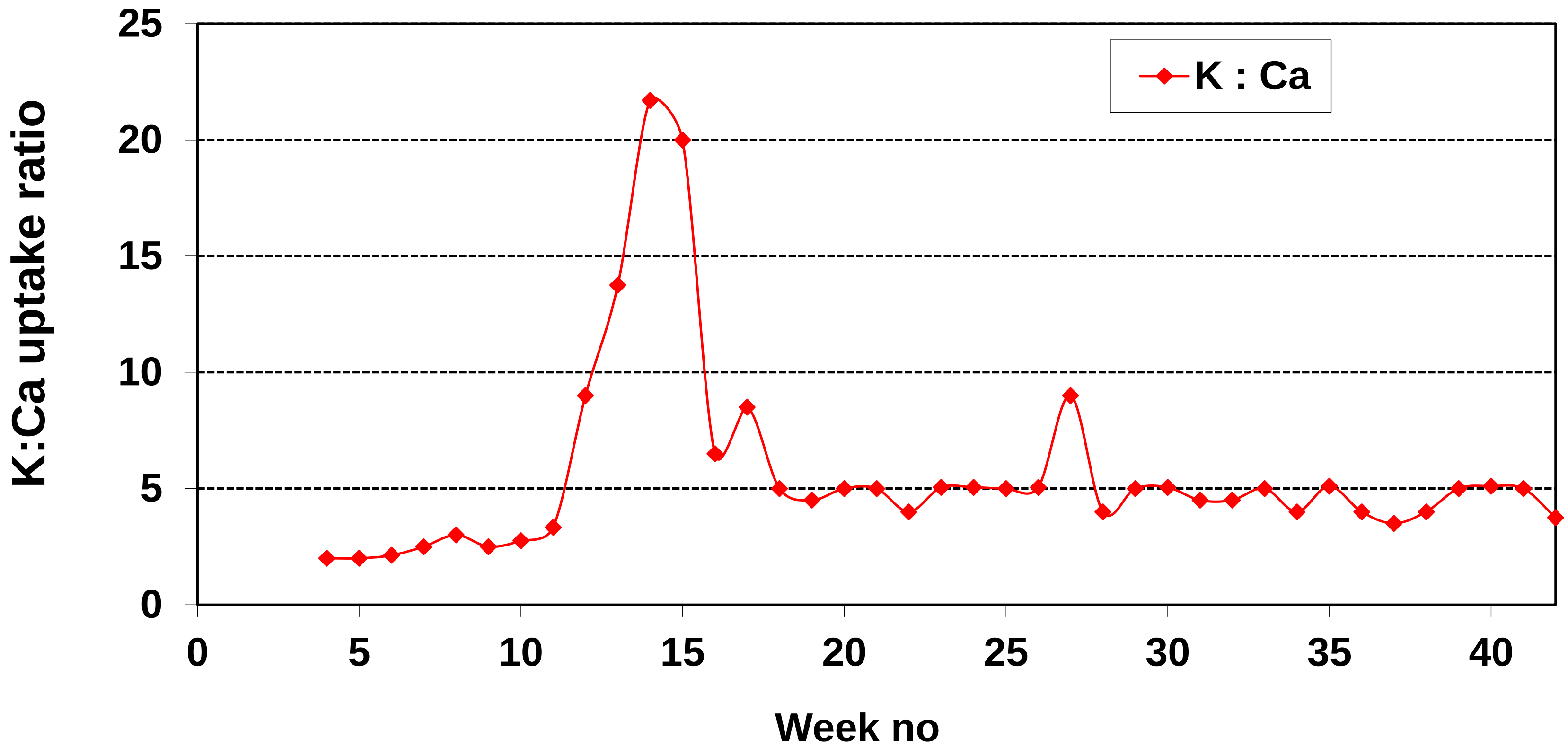
POTASSIUM and CALCIUM UPTAKE RATIO IN TOMATOES



This experiment dates from the mid 80’s, when crop fruit loads were allowed to go high
Modern crop steering prevents such high loads and the K : Ca inputs can be lower

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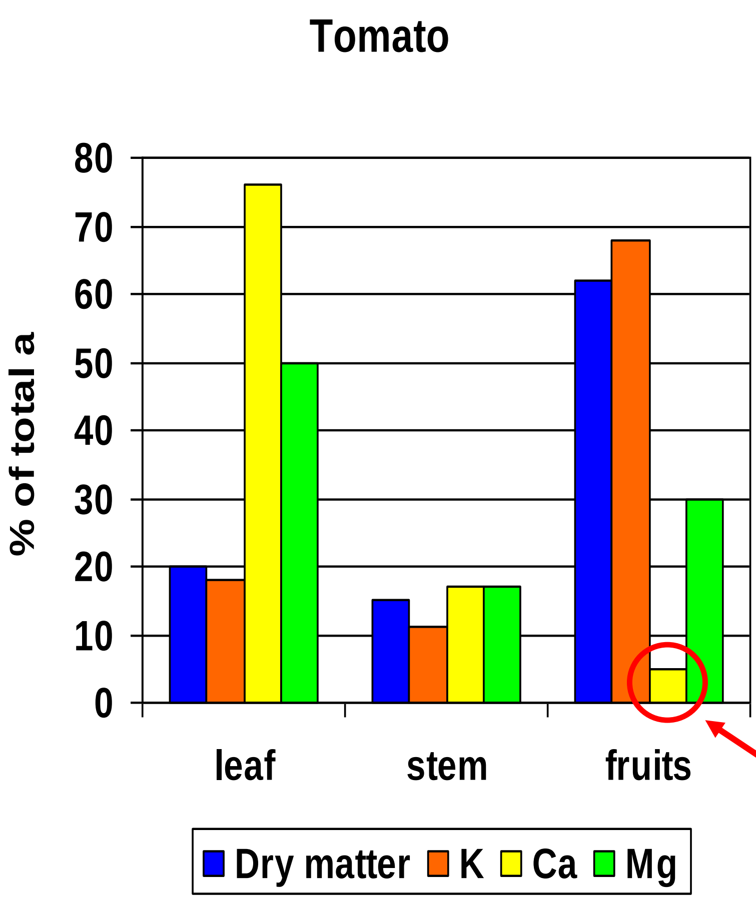
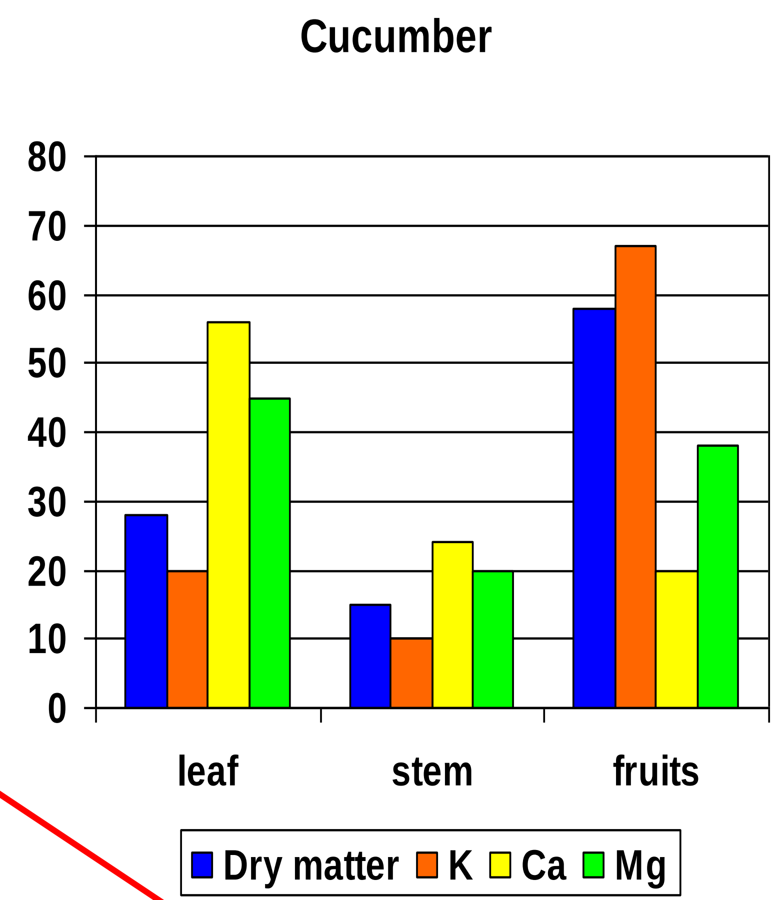
PARTITIONING OF DRY MATTER, K, Ca and Mg IN THE PLANT





High % DM to fruits; K:Ca leaves 0,3 ; K:Ca fruits 3 – 140:1 !!

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ORIGINAL NAALDWIJK FEED RECIPE CHANGES IN TOMATOES

	NH_4 N	NO_3 N	P	K	Ca	Mg	Fe	K:Ca	EC
Open + Ca	15	270	40	430	240	70	4,0	1,8	3,0
Open + K	15	275	30	490	220	60	2,0	2,2	3,0
Start (wet up)	12	223	45	400	400	80	1,5	1,0	4,0
Before truss 1	6	130	20	210	125	30	1,5	1,7	1,6
1 truss	6	130	20	240	110	25	1,5	2,2	1,6
4 truss	6	130	20	260	100	22	1,5	2,6	1,6
7 truss	6	130	20	280	95	20	1,5	2,9	1,6
10 truss	6	120	20	265	120	27	1,5	2,2	1,6
14 truss	6	120	20	235	130	30	1,5	1,8	1,6

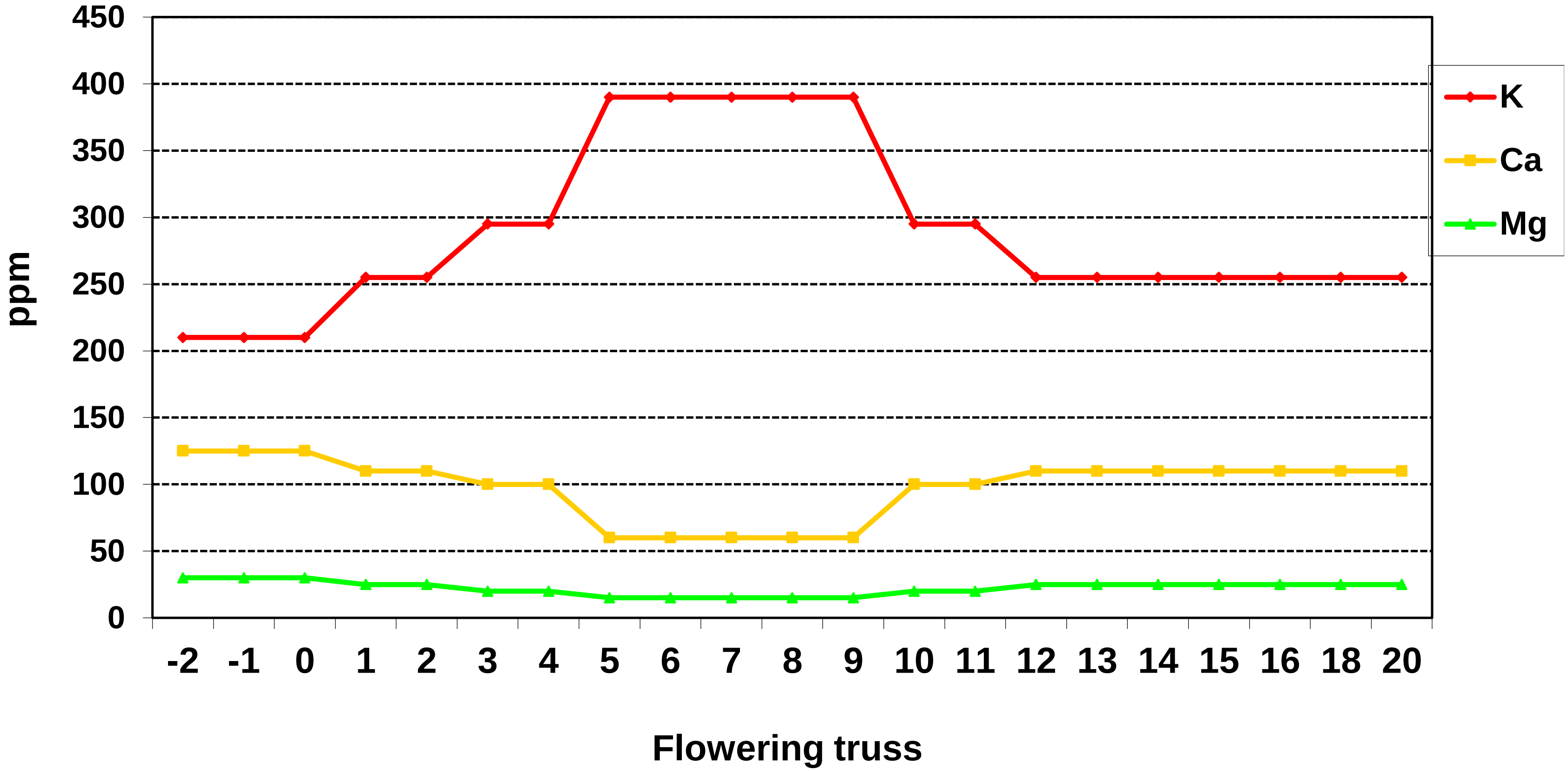
The original closed recipes had a very high K:Ca at max fruit load
In practice they are too high, due to better control over fruit load. K:Ca 2,4 is usually max
The actual change points depend on tomato ”mix” on the nursery. It is better to focus on the K:Ca in the slab/ drain water rather than the specific flowering truss.

FEED RECIPE CHANGES IN CUCUMBERS

	NH_4 N	NO_3 N	P	K	Ca	Mg	Fe	K:Ca	Lv
Open Normal	18	235	40	315	160	35	2,0	1,8	2,1
Open High Fruit load	7	280	40	420	210	55	2,0	2,0	2,8
Start	7	300	40	290	310	50	2,0	0,9	3,0
Normal	7	170	30	255	110	25	1,2	2,3	1,5
High Fruit load	7	170	30	315	80	25	1,2	3,9	1,5
Low N	7	140	30	275	100	25	1,5	2,8	1,5

Again in practice it is very unusual to go as high as K:Ca 3,9

FEED RECIPES AND CHANGES: TOMATO



As the K is increased in the recipe, both the Ca and Mg are decreased
The increasing fruit load is deciding the uptake ratios

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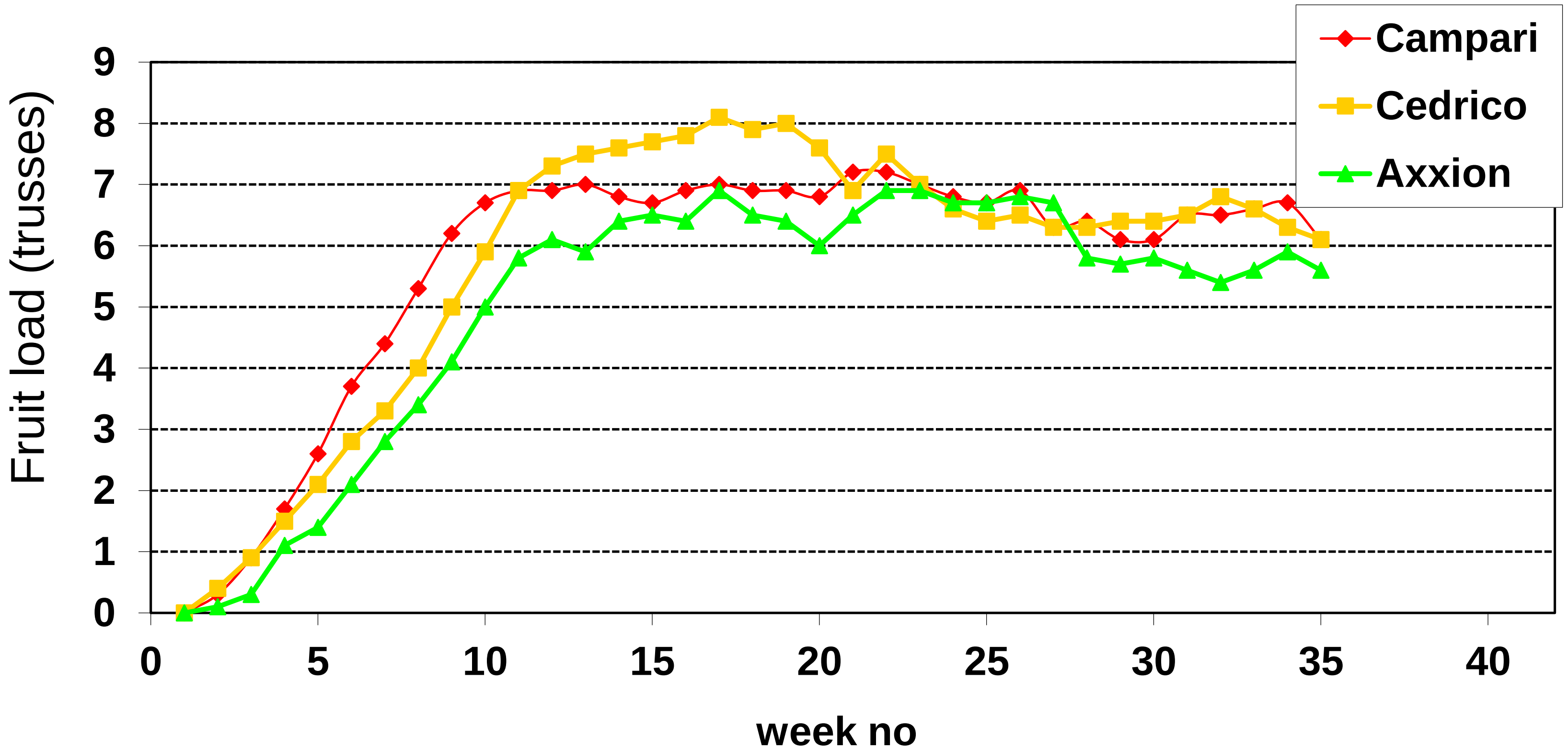
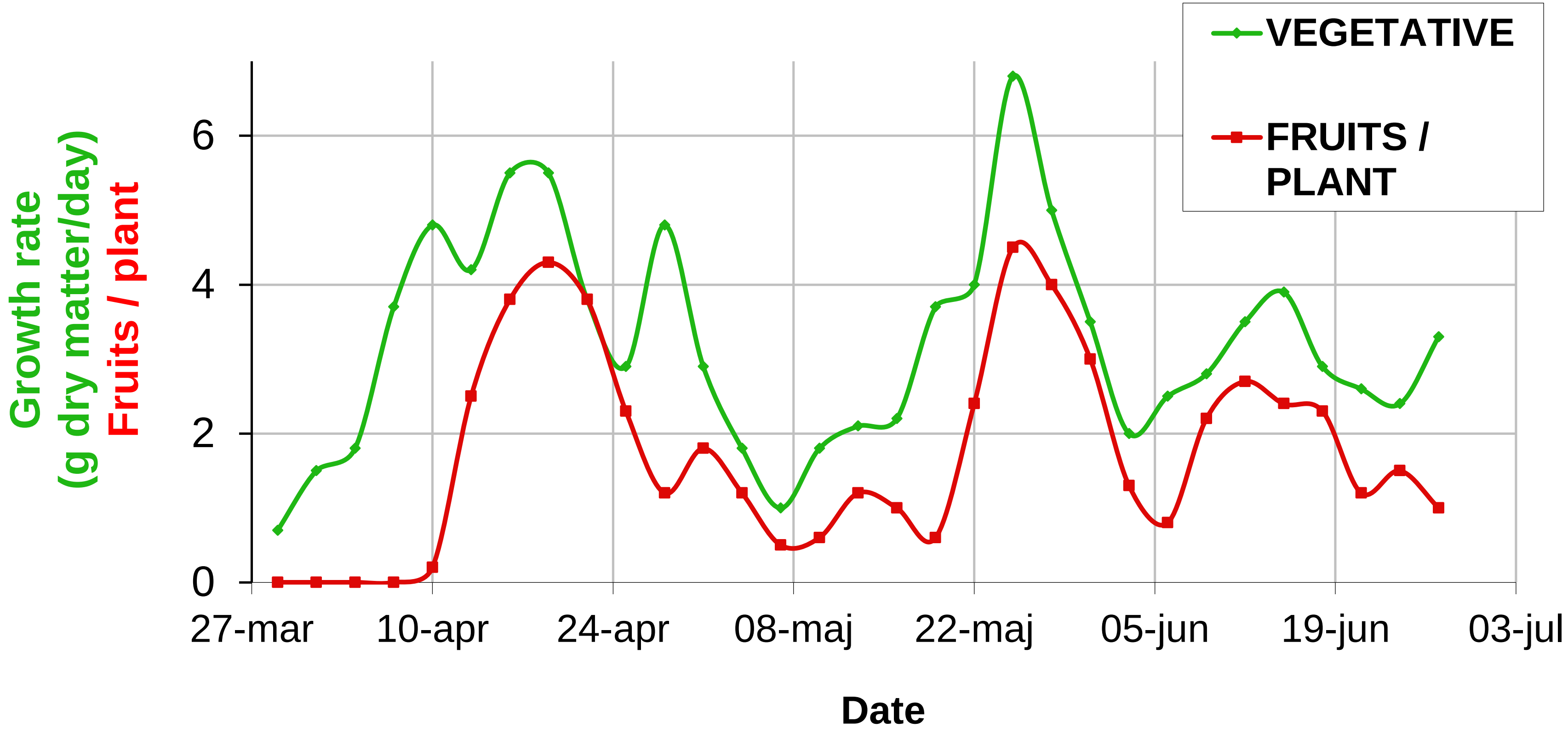
DIFFERENCES IN FRUIT LOAD OF DIFFERENT TYPES and VARIETIES



NB Data from same sowing date and nursery

DIFFERENCES IN FRUIT LOAD: CUCUMBERS



Marcellis 1992

Data from an umbrella culture

Fruit load much more constant on high wire lit crops

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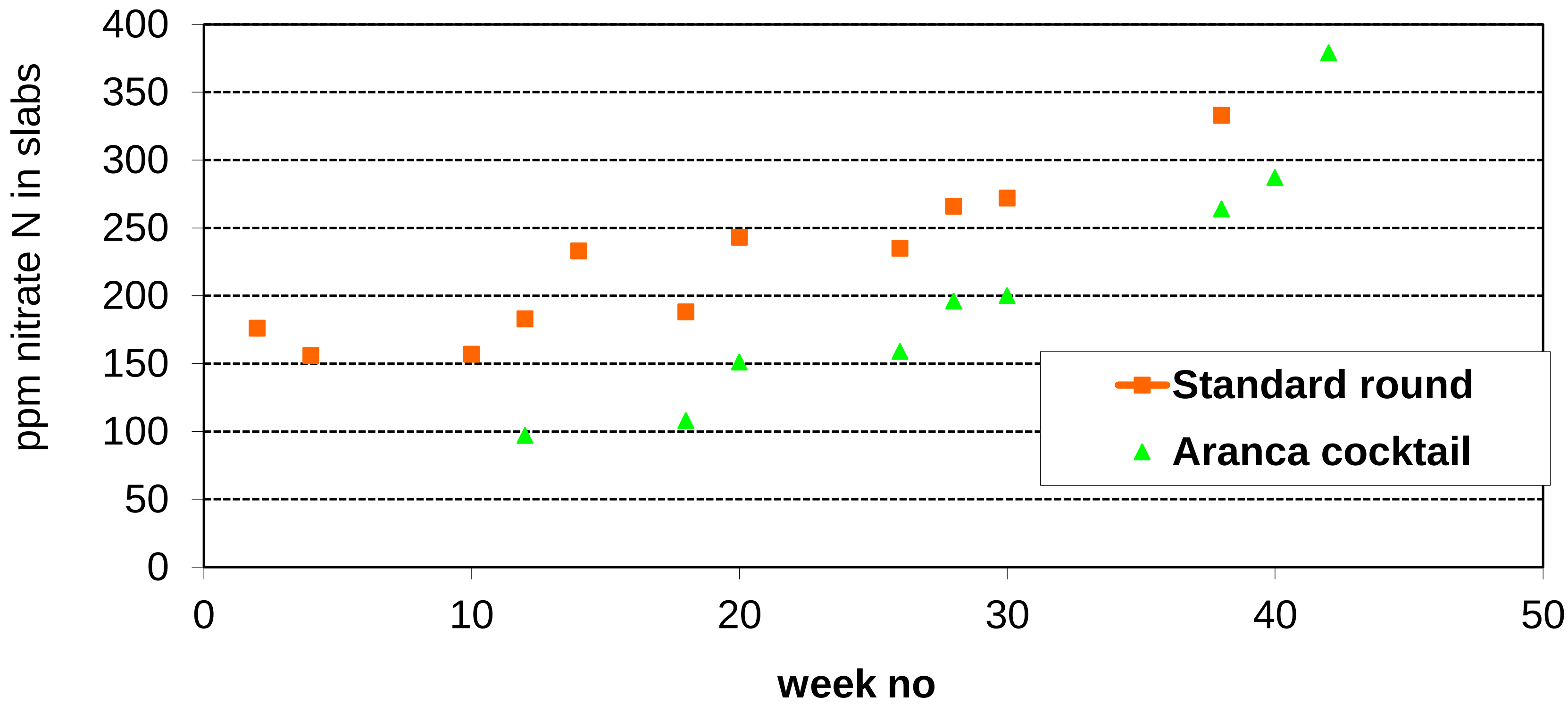
DIFFERENCES IN FRUIT LOAD OF DIFFERENT TYPES and VARIETIES: NITRATE N LEVEL IN SLABS



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ANALYSES

- It is necessay to take more frequent analysis of the drain water, incuding bicarbonate, to take into account the rapid changes in plant uptake. Analysis of drip needed to check mixer function
- Tomatoes:
  - 1 per week from the start to flowering of truss 15
  - 1 per fortnight from truss 15
  - It is also necessary to take analyses of the slabs/ drain, to take into account the differences in uptake between tomato types and varieties, especially from truss 4 – 12 every 14 days
- Peppers:
  - Once every 1-2 weeks depending on plant load and sensitivity to BER
- Cucumbers:
  - Depends on knowledge of fruit load. If constant – 1 every 2 weeks

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SOME PRACTICAL POINTS (1)

- 100% of phosphate needs to be from mono potassium phosphate instead of phosphoric acid
- Weaker acid mix for pH control
- Fosfit (plant unavailable P) added to the sysytem will show up in the analysis as plant available P

SOME PRACTICAL POINTS (2)

- Remember:
  - The nutrient balance in the drain will be affected by the the plants changing uptake
  - EC and pH can change quickly
  - Variations and ”problems” are flattened out/ disappear in open systems, but are accentuated in closed systems
  - Chelated nutrients are sensitive to UV treatment - often lost completely. Extra micro chelate has to be added when using UV and active charcoal filters

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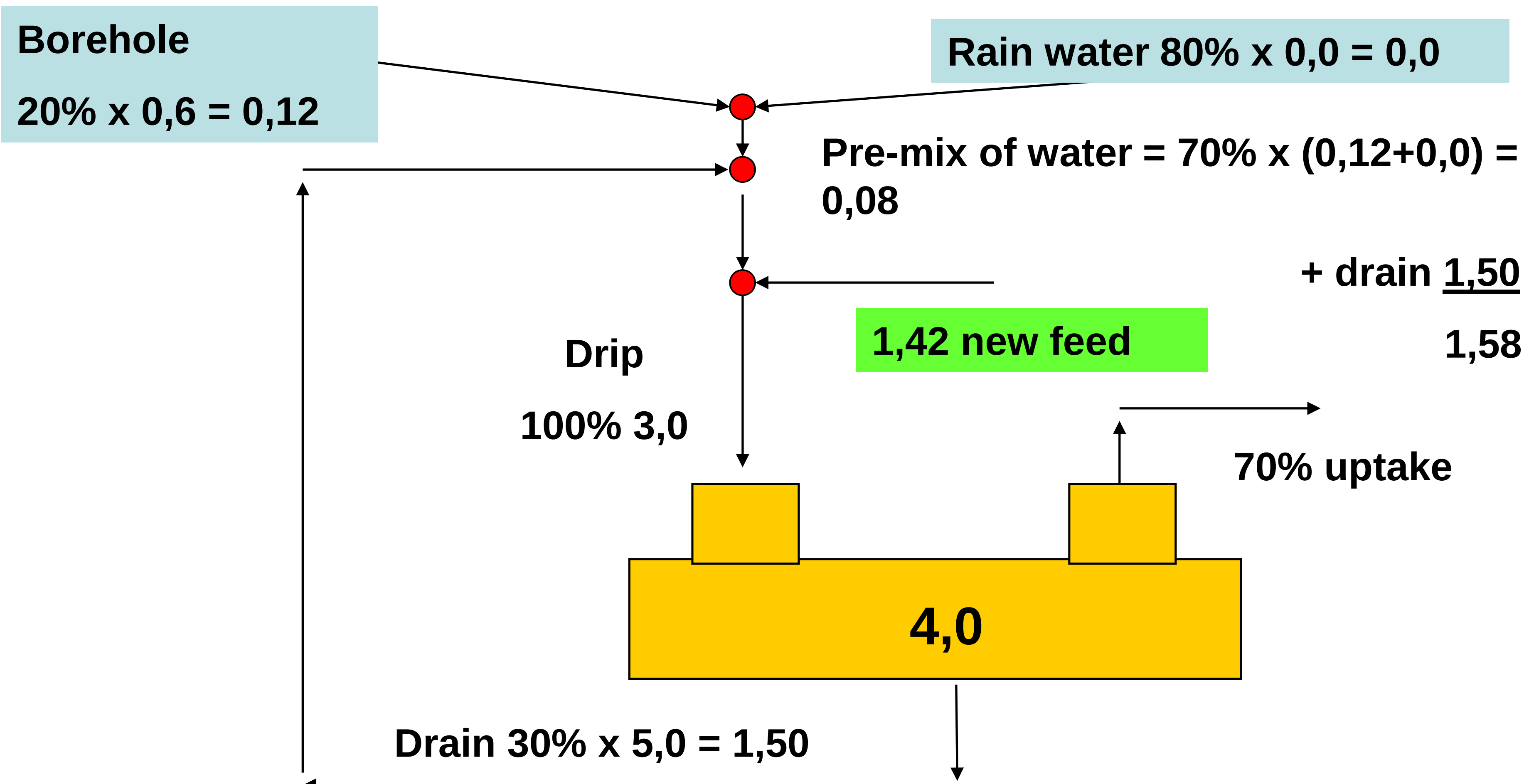
EC CONTROL IN PRACTICE IN CLOSED SYSTEMS



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MIXERS

How many nutient tanks?

- The simplest is 2 nutrients + 1 acid.
  - Easy to monitor levels
  - Easy to check flow and clean filters
  - Fertilizer amounts need to be changed at each recipe change
  - Solubility dependent on least soluble fertilizer
- Most complex is 9/10 for nutrients + 1 acid
  - More difficult to check levels and flow
  - Many valves to check and filters to clean
  - Fertilizer amount per tank is constant and kept at maximum solubility. Reduced mixing time
  - Amount added is done by adjusting l/m^3 on the computer
  - If the tanks are large enough for the main fertilizers, big bags or whole pallets can be added at each mix

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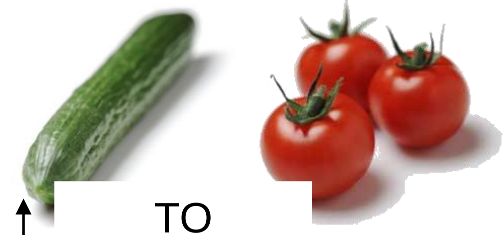
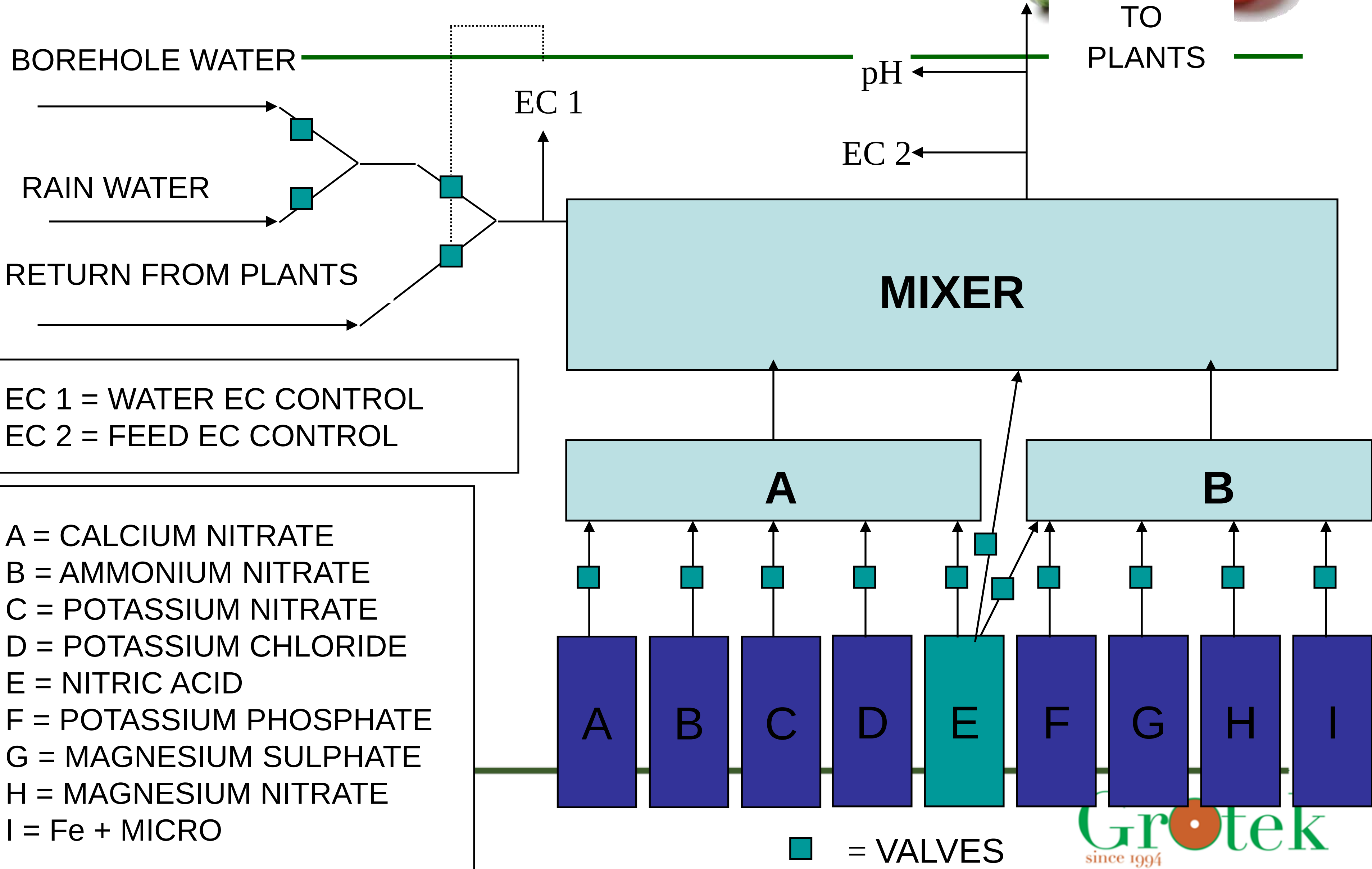
MIXERS: NL / APTR





EC 1 = WATER EC CONTROL
EC 2 = FEED EC CONTROL

A = CALCIUM NITRATE
B = AMMONIUM NITRATE
C = POTASSIUM NITRATE
D = POTASSIUM CHLORIDE
E = NITRIC ACID
F = POTASSIUM PHOSPHATE
G = MAGNESIUM SULPHATE
H = MAGNESIUM NITRATE
I = Fe + MICRO

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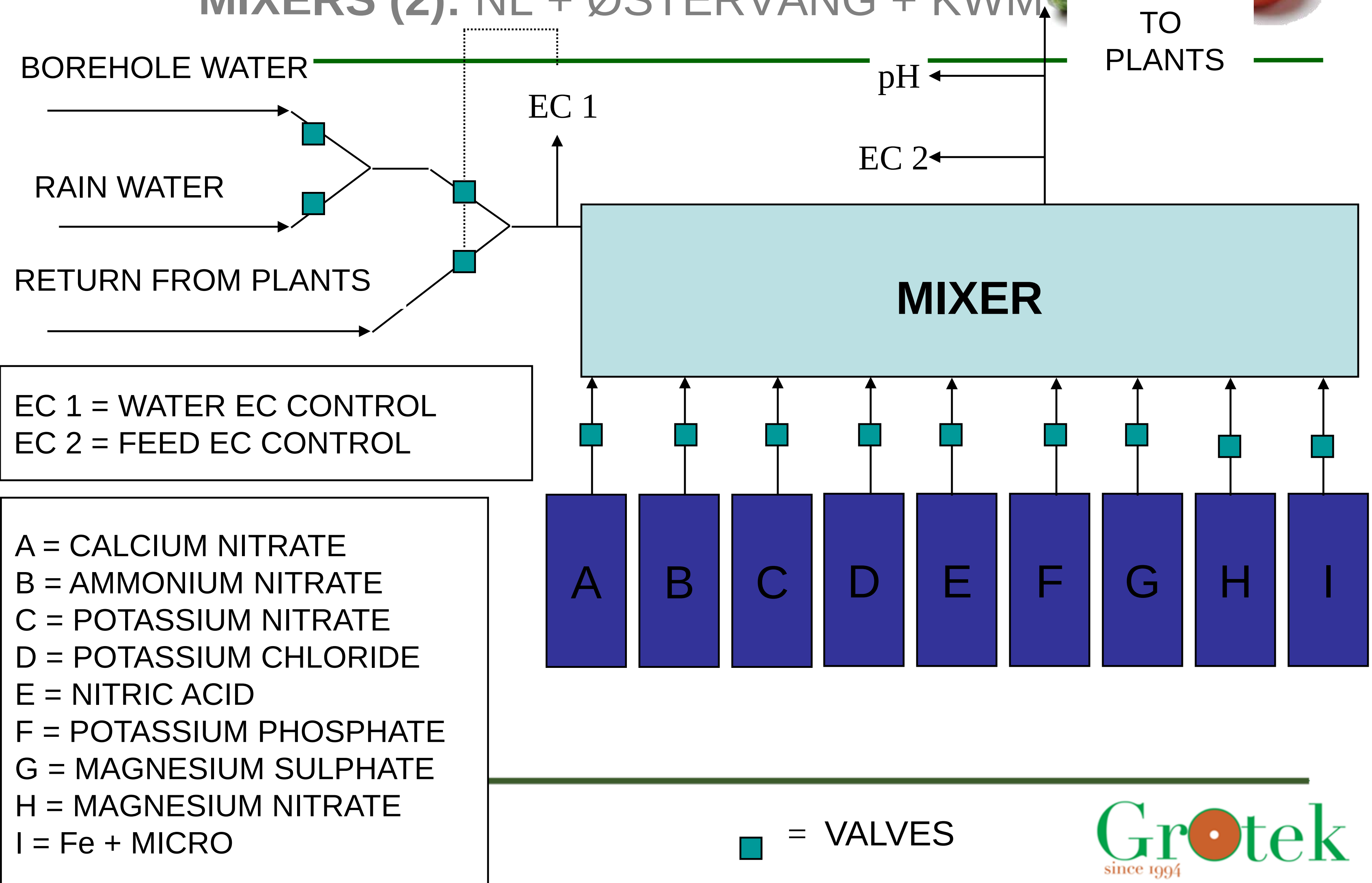
MIXERS (2): NL + ØSTERVANG + KWM



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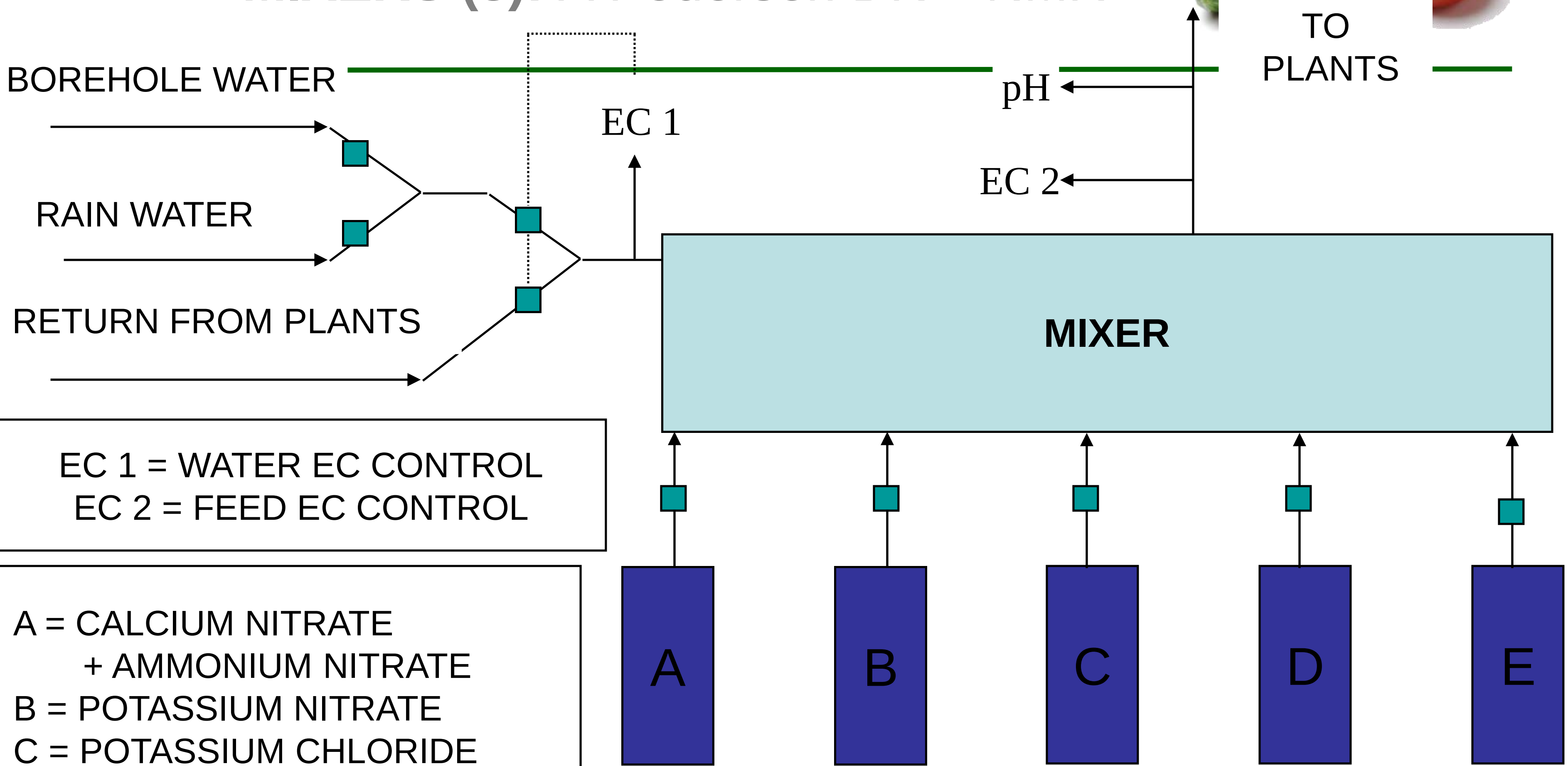
MIXERS (3): A Pedersen DK + NMR

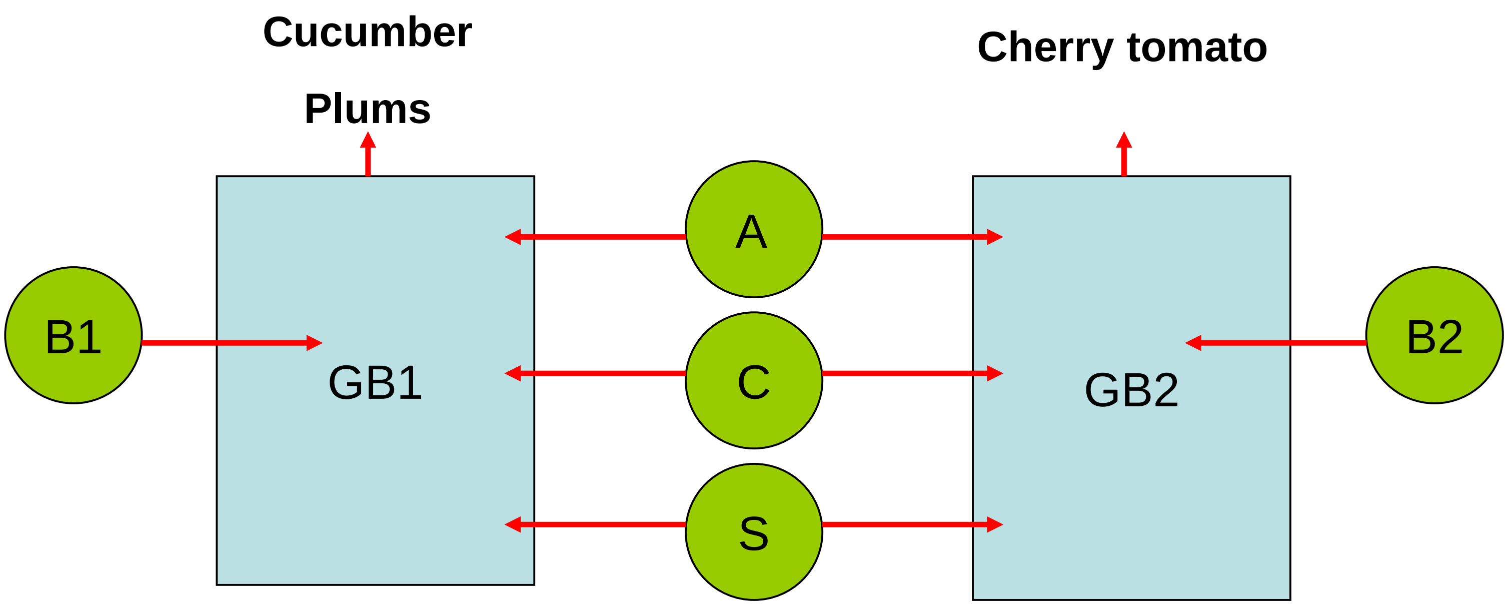


EC 1 = WATER EC CONTROL
EC 2 = FEED EC CONTROL

A = CALCIUM NITRATE
+ AMMONIUM NITRATE
B = POTASSIUM NITRATE
C = POTASSIUM CHLORIDE
+ POTASSIUM SULPHATE
+ POTASSIUM PHOSPHATE
+ MAGNESIUM SULPHATE
D = Fe + MICRO
E = NITRIC ACID

■ = VENTILER

MIXERS (4): Kaare Wiig (N)



A = Calcium nitrate

B1 + B2 = Potassium nitrate + potassium chloride + potassium sulphate + ammonium nitrate

C = Mono potassium phosphate + magnesium sulphate + micronutrients (+ potassium carbonate)

S = Nitric acid

SO HOW MANY STOCK TANKS?

- This depends on the complexity of cropping
- If you have different crop types / planting dates, then the “10 stock tank” system offers the greatest flexibility, either with direct injection (KWM), or with pre-mixing into an A + B tank (AP TR)
  - It does mean that each different crop has a valve going back to the mixer and not a common main
  - If there is only a common main, then a “day tank” is needed for each crop, which can be filled at night with the different feed
- If you have only 1 crop, then a simple A + B tank system is OK, but you have to make a new mix for each new drain analysis. Easy to make mistakes!

THE END

THANK YOU FOR ATTENTION

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