Maximizing Nitrogen Use Efficiency in Long Term High Yielding Soilless Grown Tomato.

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Fertilisation approach in greenhouse crops

- High growth rate, High yields

  Tomato 700 – 900 T/ha
  Pepper 350- 400 T/ha

  58 – 72 T dry matter/ha
  net uptake:

  1400 – 1800 kg N/ha

  400 – 500 kg P/ha

  2300 – 3000 kg K/ha

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Fertilisation approach in greenhouse crops

Nutrient management =
taking into account requirements for:

- Crop,
- Soil / growing medium,
- Water quality
- Interactions between nutrients
- Specific fertilizer effects
- Impact on environment

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Soil-less culture

- Roots in restricted volume
- Disconnected from natural soil

- Growing medium (Substrate culture)
- Water (Hydroponics)
- Water + Nutrient solution + Medium

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Fertilisation in greenhouse crops

100 % Fertigation

1. Concentrations instead of quantities
   - fertigation / soil solution
   - EC, Nutrients mg/l or mmol/l
2. Nutrient ratio's
   - K : Ca ,
     N : K ,
     Ca : Mg
     e.g.

Nutrient solutions

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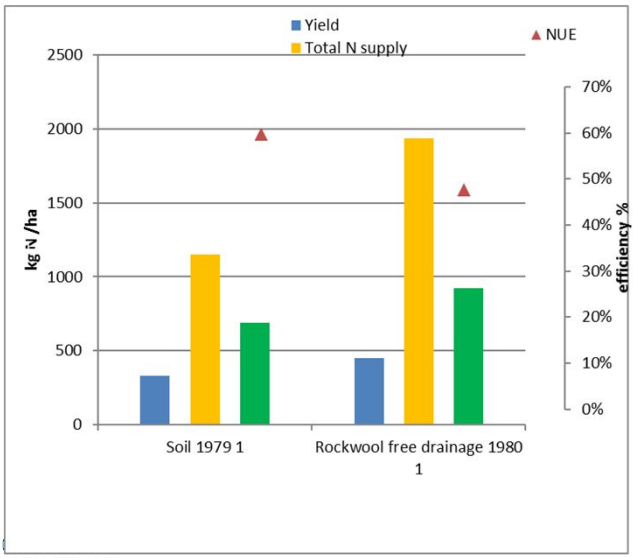
NUE in soilless culture '80-ies



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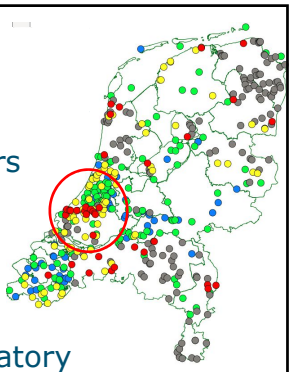
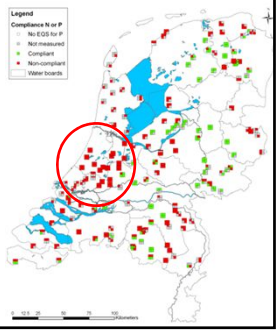
Greenhouses in Netherlands

- High leaching rate, pollution surface waters
- EU Nitrate Directive,
- EU Water Frame Directive
- Regulations
  - Recirculation of drainage water obligatory





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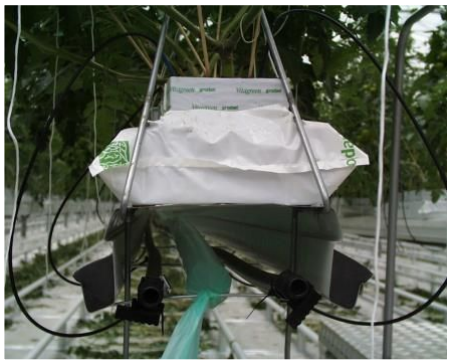
Rock wool culture

Fruit vegetables

Suspended troughs



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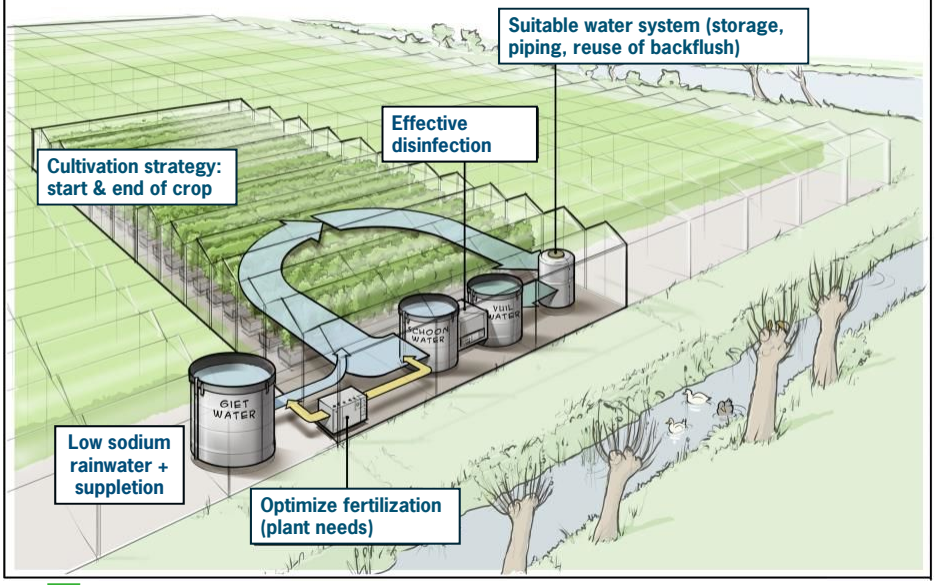
Zero-discharge in soilless crops



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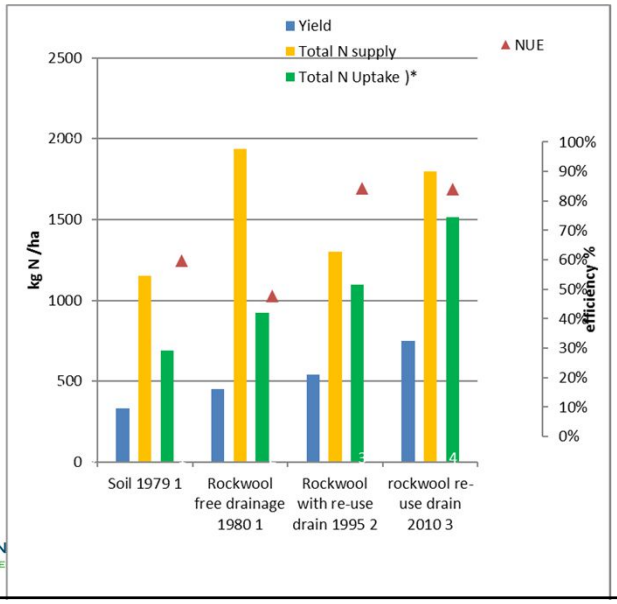
Development in NUE



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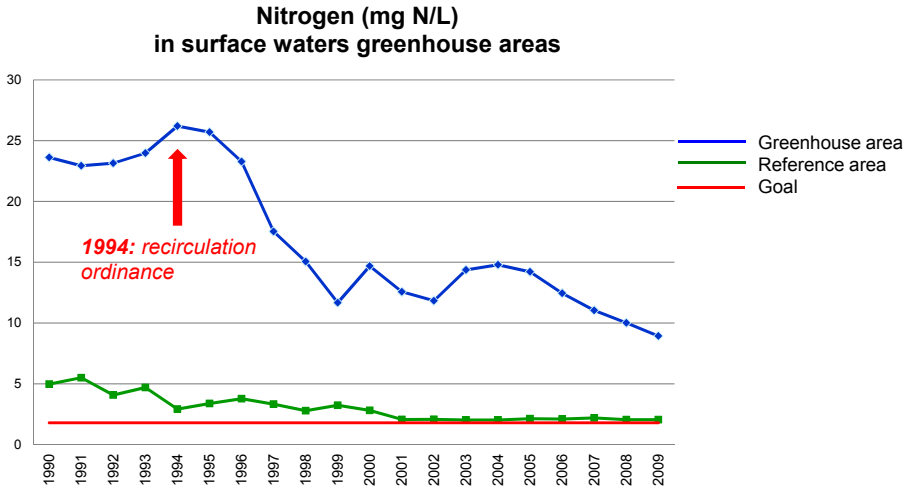
However……



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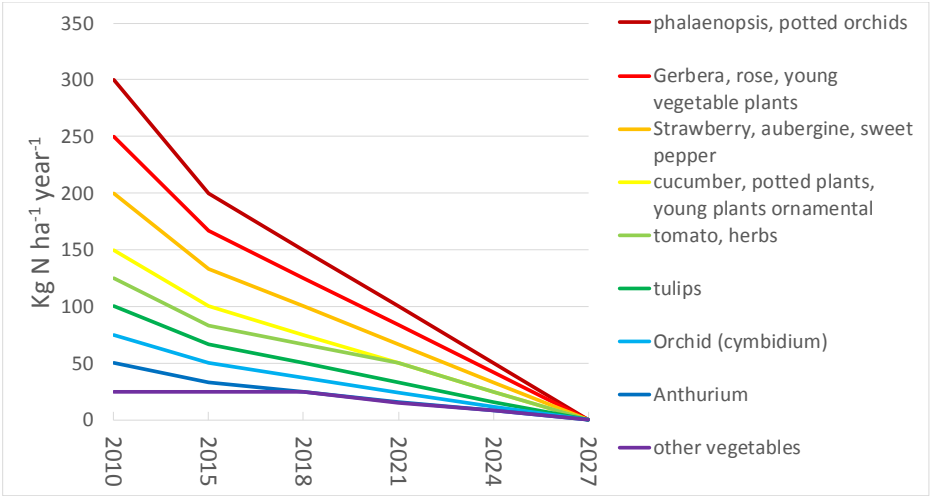
Data: Hoogheemraadschap van Delfland

Nitrogen emission standards (soilless crops)



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How to further reduce N (NO_3) -emissions

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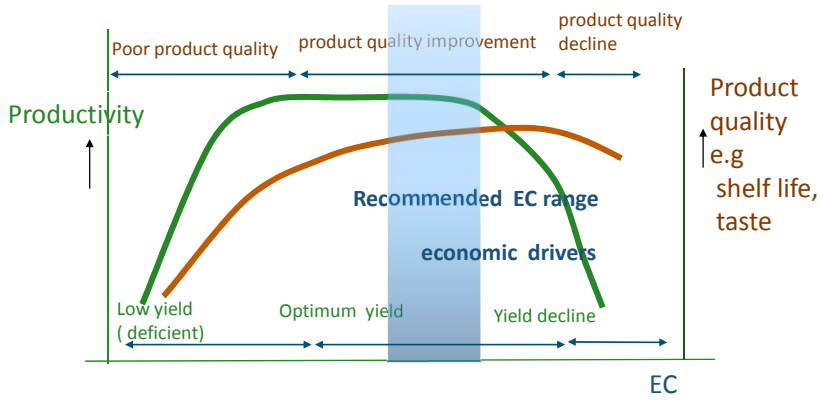
Effect of EC on crops



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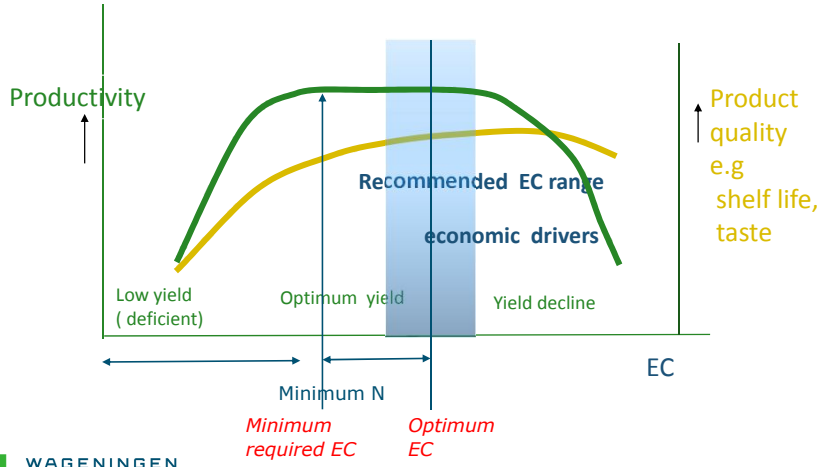
Effect of EC on crops



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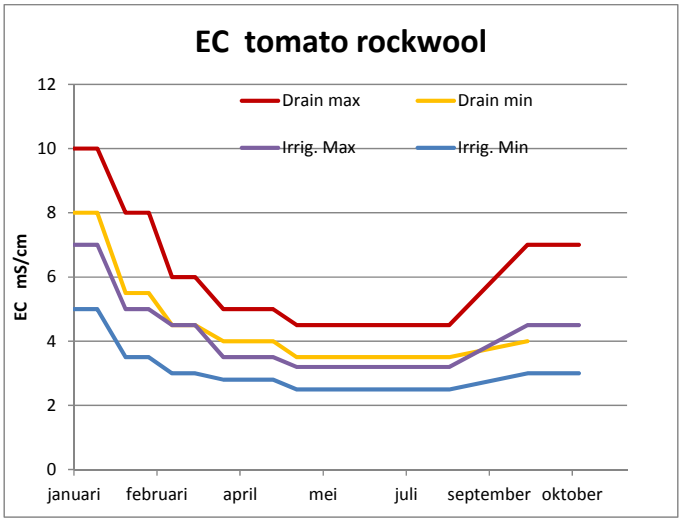
Recommended EC during season



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Nutrient solution tomato

Tomato Open system, (free drainage)	EC dS.m-1	NH4	Na	K	Ca	Mg	NO3	Cl	SO4	H2PO4	N-total	
		mmol.l-1									mmol/l	mg/l
Standard												
supply	2.6	1.2		9.5	5.4	2.4	15.8		4.5	1.5	17.0	238
Target Root env.	3.7	0.1		8.0	10.0	4.5	24.0		6.0	1.0	24.1	337

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Manipulation of nutrient solution

Tomato Open system, (free drainage)	EC	NH4	Na	K	Ca	Mg	NO3	Cl	SO4	H2PO4	N-total	
	dS.m-1					mmol.l-1					mmol/l	mg/l
Standard												
supply	2.6	1.2		9.5	5.4	2.4	15.8		4.5	1.5	17.0	238
Target Root env.	3.7	0.1		8.0	10.0	4.5	24.0		6.0	1.0	24.1	337
minimum required												
supply	1.45	0.5		6.5	2.3	1.5	11.0		1.4	0.8	11.5	161
Target Root env.		0.0		2.0	6.0	3.0	4.0		2.0	0.5	4.0	56

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Manipulation of nutrient solution

Tomato Open system, (free drainage)	EC	NH4	Na	K	Ca	Mg	NO3	Cl	SO4	H2PO4	N-total	
	dS.m-1					mmol.l-1					mmol/l	mg/l
Standard												
supply	2.6	1.2		9.5	5.4	2.4	15.8		4.5	1.5	17.0	238
Target Root env.	3.7	0.1		8.0	10.0	4.5	24.0		6.0	1.0	24.1	337
minimum required												
supply	1.45	0.5		6.5	2.3	1.5	11.0		1.4	0.8	11.5	161
Target Root env.		0.0		2.0	6.0	3.0	4.0		2.0	0.5	4.0	56
"space" for additional salts												
supply	2.63	0.5	11.8	6.5	2.3	1.5	11.0	11.8	1.4	0.8	11.5	161
Target Root env.		0.0	17.0	2.0	6.0	3.0	4.0	28.5	2.0	0.5	4.0	56

Theoretically 2.6 dS/m space for reduction of N

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Experiments with reduced N concentrations

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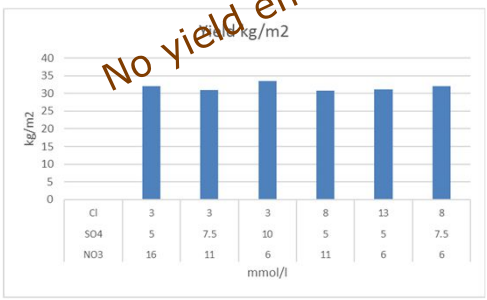
N – ratios (anions)

- Round tomato crop, hydroponics (NFT)
- March - October

Nukaya et al. 1991



Treatment No.	NO_3:SO_4:Cl (mmol/l)
1.	16: 5 : 3
2.	11: 7.5 : 3
3.	6: 10 : 3
4.	11: 5 : 8
5.	6: 5 : 13
6.	6: 7.5 : 8

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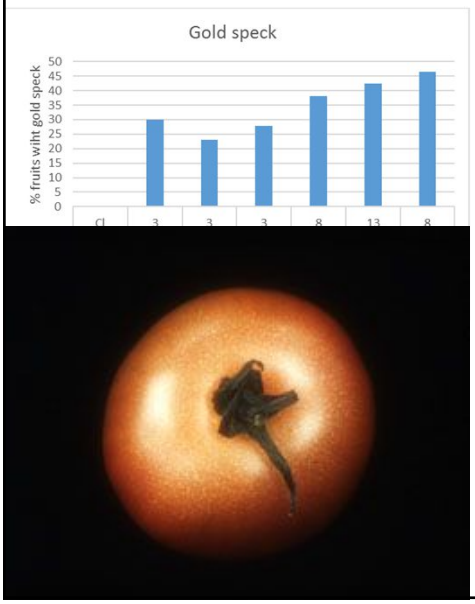
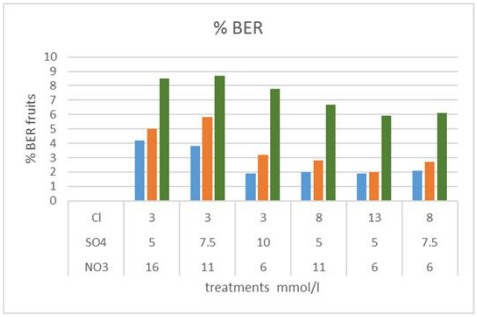
External quality





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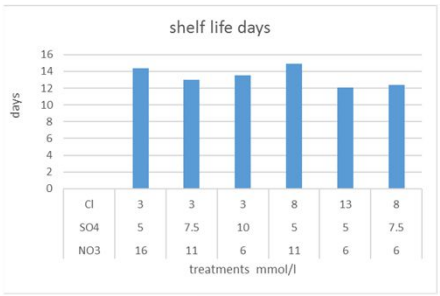
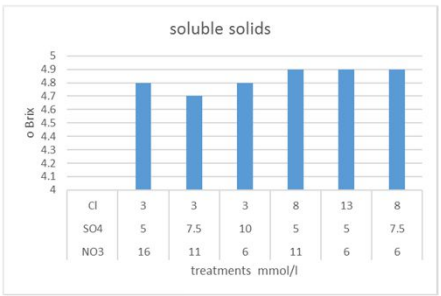
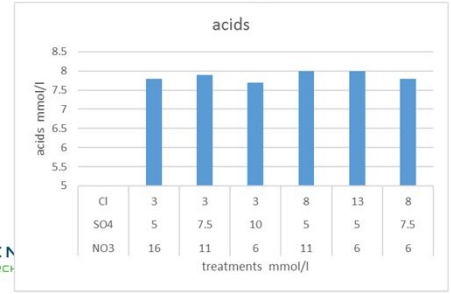
Shelf life and taste parameters







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Effect of NO_3 : Cl – ratios;
tomato rockwool closed system

Treatments	Spring crop					Autumn crop		
	EC	NO_3		Cl		EC	NO_3	Cl
	mS/cm	mmol/l	*ppm N*	mmol/l	*ppm Cl*	mS/cm	mmol/l	mmol/l
1	3.7	22.8	*319*	0.5	*18*	3.7	24	0.5
2	3.7	13	*182*	9.9	*351*	3.7	9	14.1
3	3.7	8.1	*113*	14.3	*508*	3.7	6.2	16.2
4	3.7	3.1	*43*	17.8	*632*	3.7	4.4	16.7
5*	3.7	1	*14*	19.9	*706*	3.7	1.7	18.6
6**	3.7	0.8	*11*	23.6	*838*	3.7	1.1	20.2

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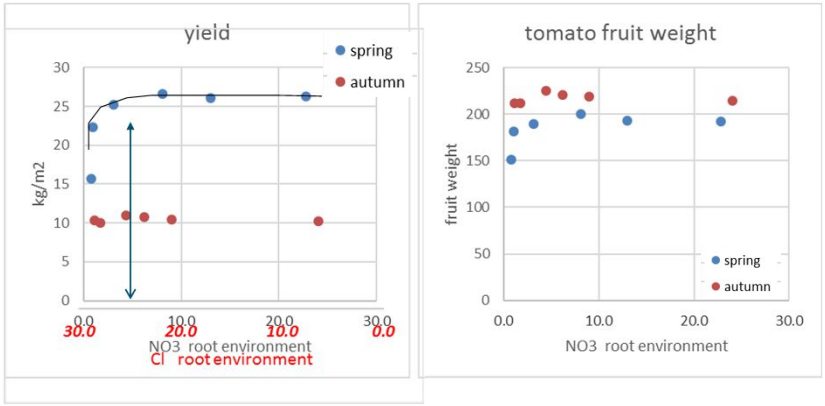
Yield

NO_3 supply varied, by replacing with Cl.

Closed recirculation system



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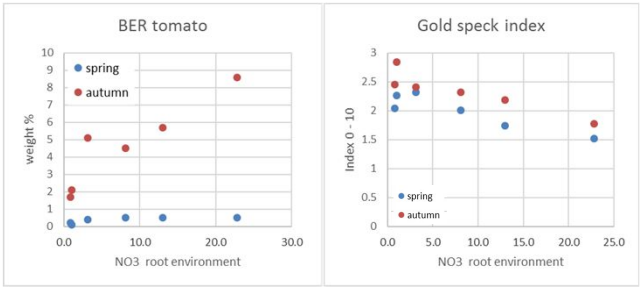
From: Voogt and Sonneveld, 2004. Acta Hort. 644

External quality



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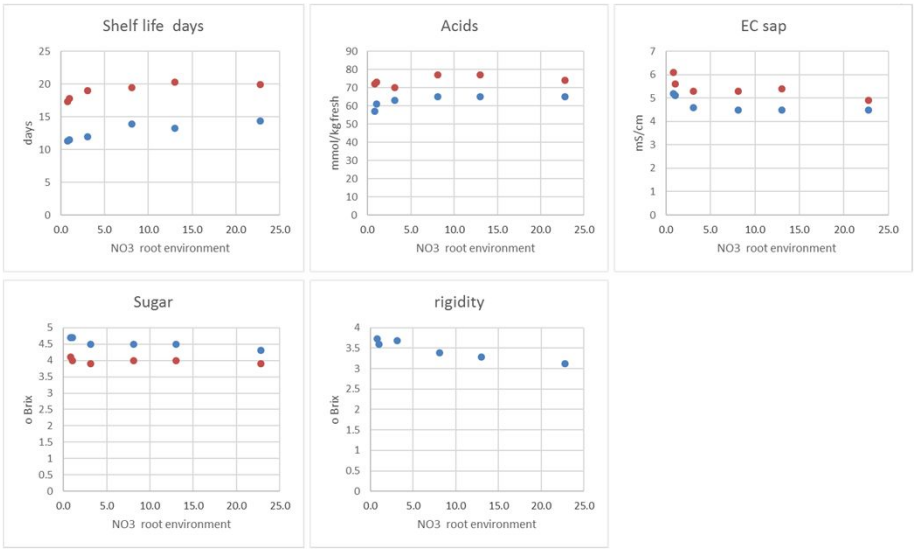
Shelf life - internal quality



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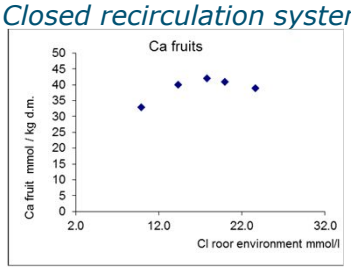
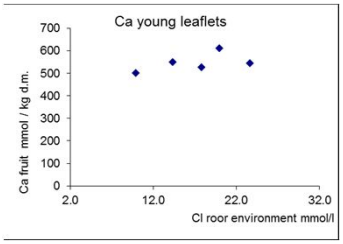
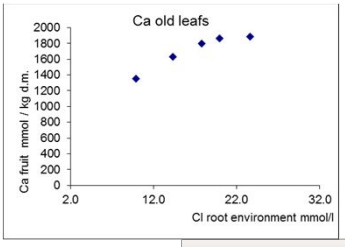
Effect on Ca- uptake

NO_3 supply varied, by replacing with Cl.

Closed recirculation system







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From: Voogt and Sonneveld, 2004. Acta Hort. 644

Implementation in commercial practice

- Casus 1.
- Semi commercial trial. Tomato crop 8 months, four separate compartments. c.v 'Tone Guitar'. Closed system, rockwool.
- Two treatments standard and reduced NO_3/ increased Cl

	A Standard					B reduced N				
	N drain		Cl drain		NO3/Cl	N drain		Cl drain		NO3/Cl
	mmol/l	mg/l	mmol/l	mg/l		mmol/l	mg/l	mmol/l	mg/l	
Goal	20	280	< 1.5	< 50	"10"	12	168	8	284	1.5

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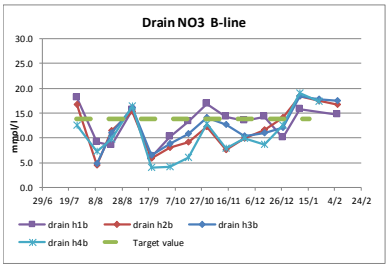
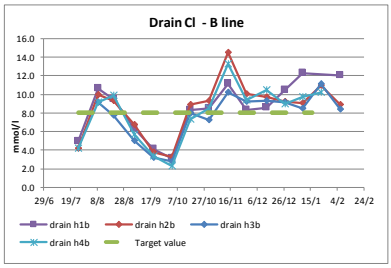
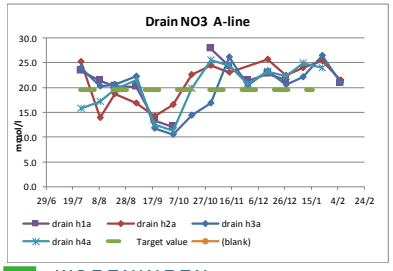
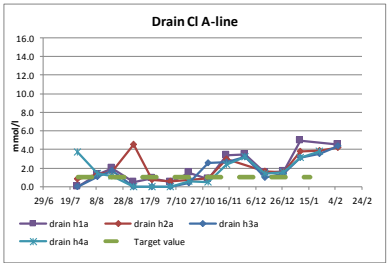
Results









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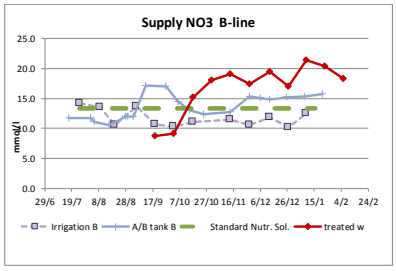
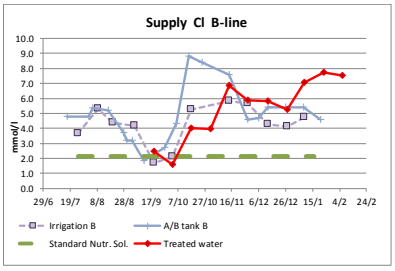
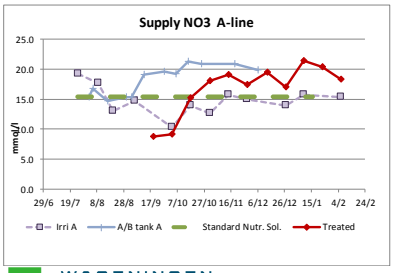
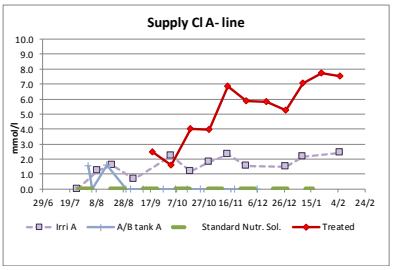
Results II









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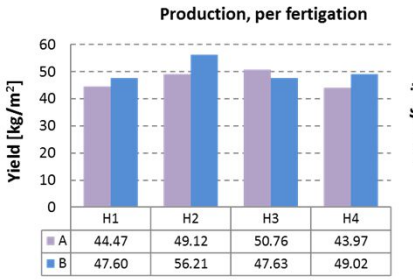
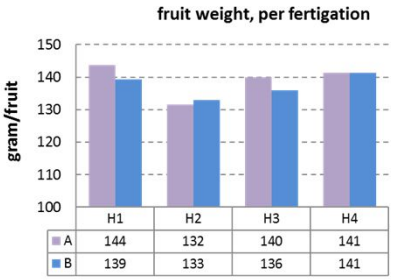
Results III





Results IV

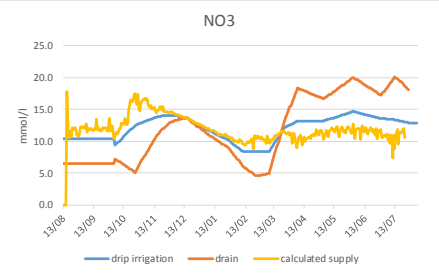
	A Standard					B reduced N				
	N drain		Cl drain		NO3/Cl	N drain		Cl drain		NO3/Cl
	mmol/l	mg/l	mmol/l	mg/l		mmol/l	mg/l	mmol/l	mg/l	
Goal	20	280	< 1.5	< 50	"10"	12	168	8	284	1.5

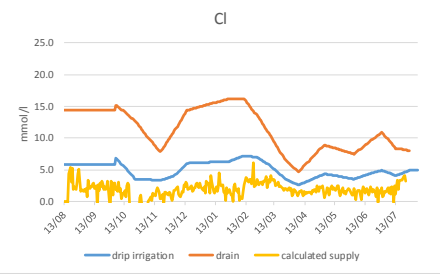
Supply (EC 2.8)	A Standard					B reduced N					NO3 reduction
	N input		Cl input		NO3/Cl	N input		Cl input		NO3/Cl	
	mmol/l	mg/l	mmol/l	mg/l		mmol/l	mg/l	mmol/l	mg/l		
Standard Nutrient Solution	15.5	*217*	0	0		13	*182*	3.5	*124.3*	1.7	16%
irrigation analysis	14.8	*207*	1.5	*54.9*	9.5	11.7	*164*	4.3	*151.4*	2.7	21%
fertiliser prepared(A/B tank)	17.2	*241*	0.0	*0.0*	76.1	13.6	*191*	4.9	*175.6*	2.8	21%

Root environment (EC 3.8)											
drain analysis	H1	23.0	*322*	1.9	*68.2*	12.0	12.9	*180*	8.4	*299.8*	1.5	44%
	H2	21.0	*294*	2.1	*73.6*	10.1	11.9	*167*	8.5	*303.0*	1.4	43%
	H3	20.0	*281*	1.7	*59.1*	12.0	12.2	*171*	7.8	*276.8*	1.6	39%
	H4	20.2	*283*	1.6	*57.7*	12.4	10.6	*148*	8.0	*285.1*	1.3	48%

Implementation

- Casus 2
- Commercial growers.





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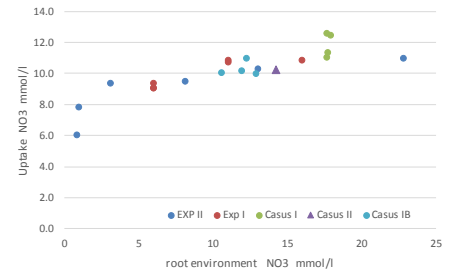
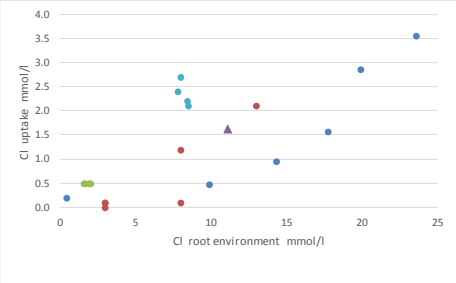
Effect of NO3/Cl





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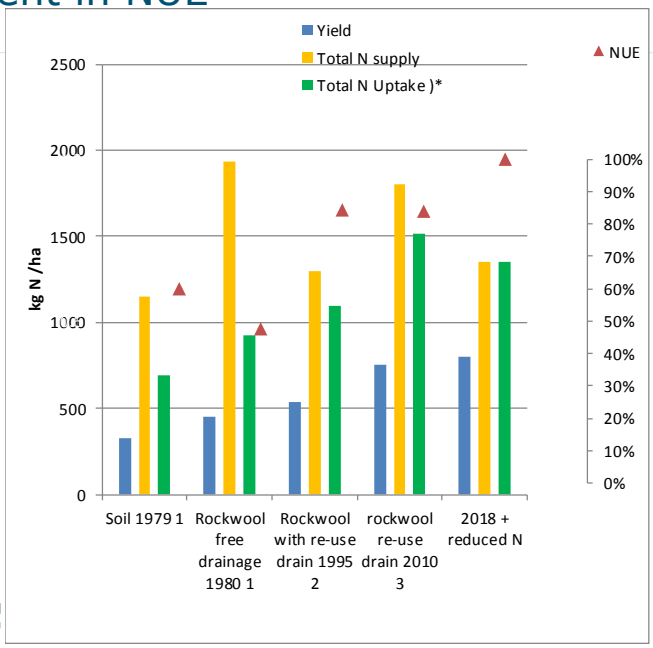
Development in NUE



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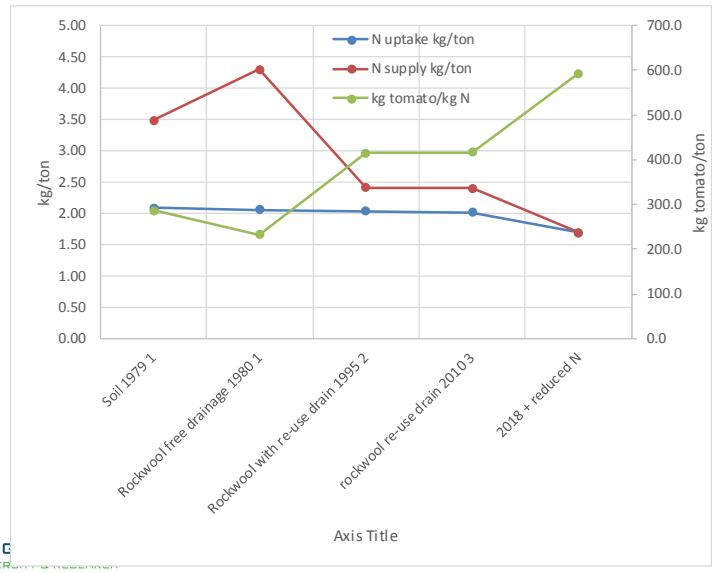
Nitrogen use Efficiencies



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Conclusions

- Soil-less crops, potentially extremely high WUE and NUE using recycling of drainage water
- Residual discharge unavoidable
- Remaining NO3 emission can be successfully diminished by reduction of NO3
- 25 % of NO3 can be safely replaced by Cl
- Almost 50 % reduction in NO3 concentration in drainage means potentially 50 % reduction in N-emission
- Side effect, better Ca uptake (?)

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