Managing chemical water quality related problems in closed hydroponic systems

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Introduction

Dutch context

(1998) Soilless growing:

- Recirculation /reuse of drainage water obligatory
- Discharge drainage water only if:
  - Na > legal limits *(differ per crop)*
  - Disease outbreak (*permission required)*
- Rainwater collection obligatory (500m^3/ha)

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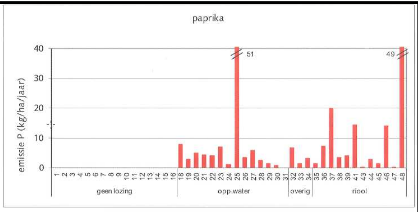
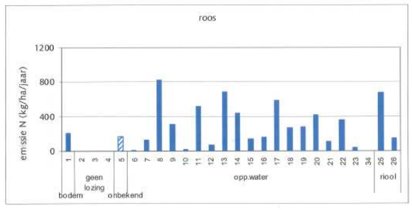
State of the art (2005)



Common growers practice:

- Frequent discharge quite common
- Significant N, P emissions + Plant Protection Chemic.
- Causes, motives
  - Disease risks
  - Na, Cl accumulation
  - Nutrient irregularities
  - Growth reduction
  - …….



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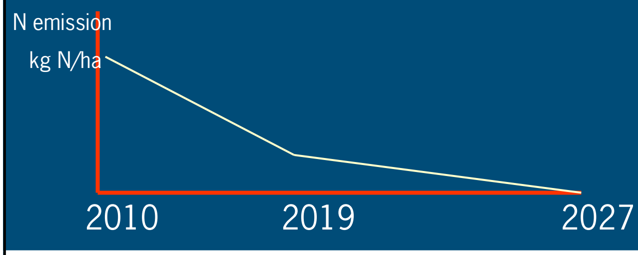
European Waterframework Directive

- GLAMI agreement: from 1-1-2010
- Emission targets to be reached
- 2027 (almost) zero emission in greenhouse industry
- ‘Target’ instead of ‘means’ regulation



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Aim: minimize discharge / emission of N,P and PPC

- Disease risks
- Na, Cl accumulation
- Nutrient irregularities
- Growth reduction
- …….

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Na and Chloride

Water source (Na en Cl)

Strongly regulated in near future

Na concentration in some water sources mmol l^{-1}

Source	remarks	EC mS/cm	Na mmol/l	Cl mmol/l
Reversed Osmosis		< 0.1	< 0.1	< 0.1
Rainwater	Coast	0.2	0.5 (>5)	0.5 (>5)
	Westland area	0.1	0.3	0.3
	Inland	< 0.1	0.05	0.05
Tap water	Source river Maas	0.48	1.25	1.1
	Source river Rhine	0.65	1.8	1.6
Surface water	Westland area	0.8	6	6
Well water	Westland area	>>2	>> 10	>>10
	South-east	0.8	0.5	0.4

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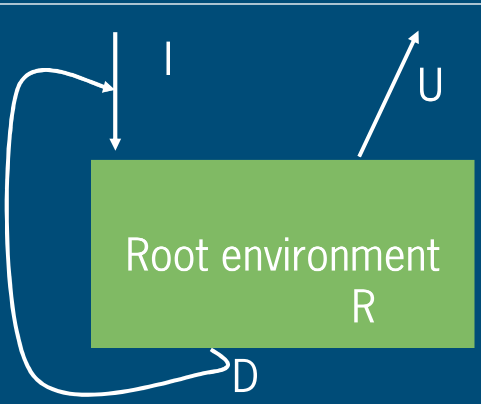
(semi) closed system



I = input concentration

U = uptake concentration

I > U accumulation

I < U depletion

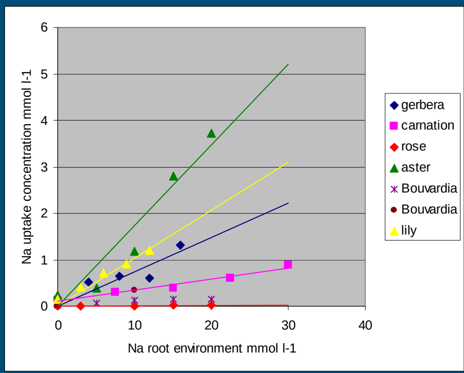
Uptake concentrations

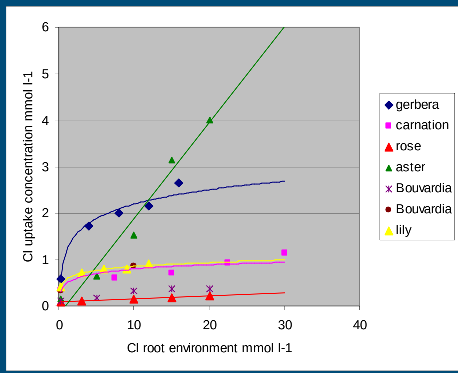
	Na		Cl	
	low	high	low	high
Aster	0.2	1.5	0.4	2
Bouvardia	0.1	0.1	0.2	0.3
Carnation	0.1	0.3	0.5	0.8
Gerbera	0.2	0.8	0.2	0.8
Lily	0.4	1	0.4	1
Rose	0.001	0.01	0.1	0.2
Cucumber	0.3	1	0.3	1
Sweet pep|	0.2	0.3	0.3	0.6
Tomato	0.4	0.8	0.6	1

Sonneveld et al., (1988, 1992,1991,2002),

Baas et al., (1994, 1996,2004)

Uptake concentrations II





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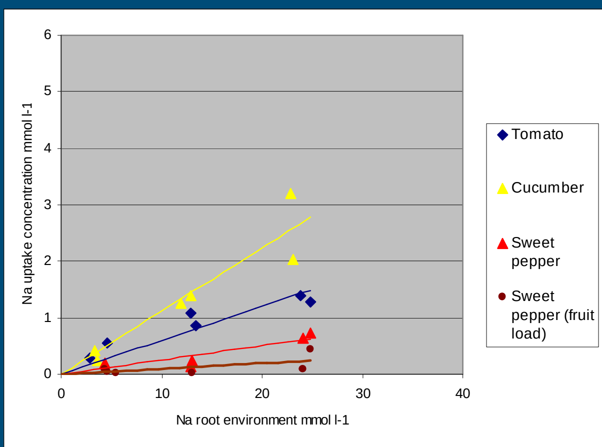
Na uptake concentrations



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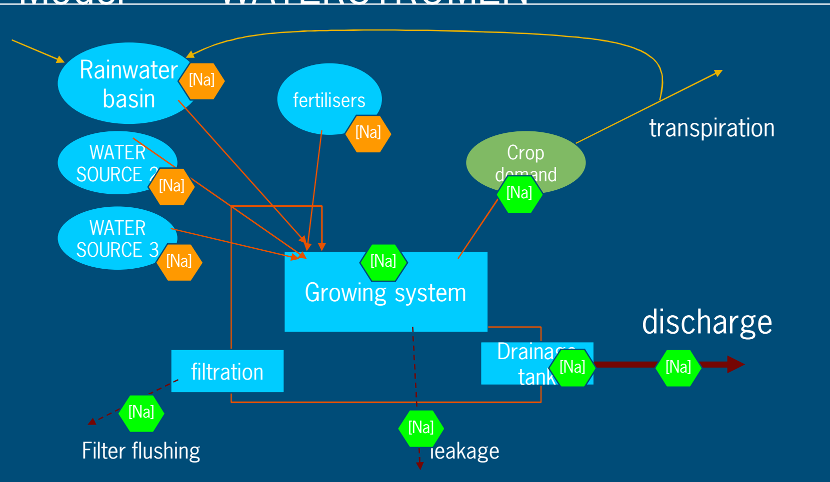
Problem

- Dynamic
  - input of Na , Cl (water source)
  - [Na] [Cl] concentration root environment
  - [Na] [Cl] uptake concentration

Model 'WATERSTROMEN'



Example Tomato, Rose

Water basin 1500 m3,
supplemental tapwater
Normal year (precipitation, climate)

Na rainwater 0.15 mMol

Na tapwater 1.5 mMol

Na $_{max}$ Rose= 4, Tomato = 6 mMol

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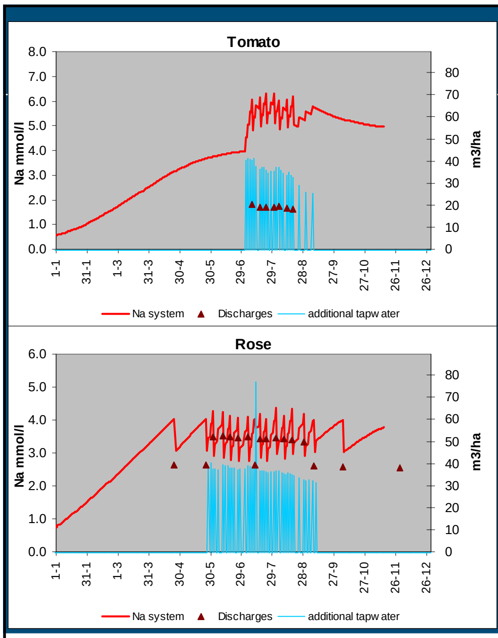

2 % discharge needed

(54 kg N/ha)

10 % discharge needed

(240 kg N/ha)

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Minimize discharge / emission of N,P and PPC

- A. Maximize Na uptake
- B. Improve discharge strategies
- C. Reduce N and P in discharge water

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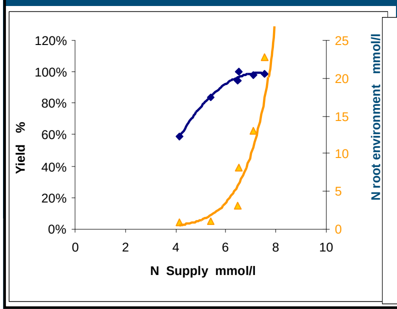
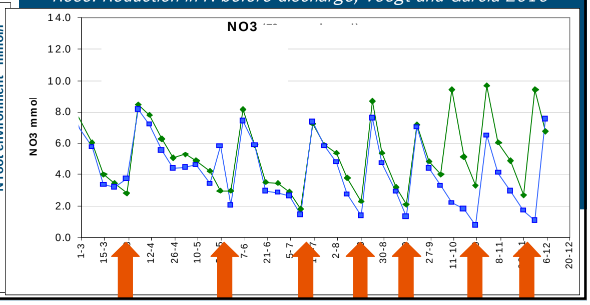
Improvements

-
-
- C. Reduce N and P in discharge water

Reduction N tomato, Voogt and Sonneveld 2004



Rose: Reduction in N before discharge, Voogt and Garcia 2010



Maximize Na uptake / removal by crop

- Increase R_{max} (Na) to max acceptable level
- Change nutrient solution

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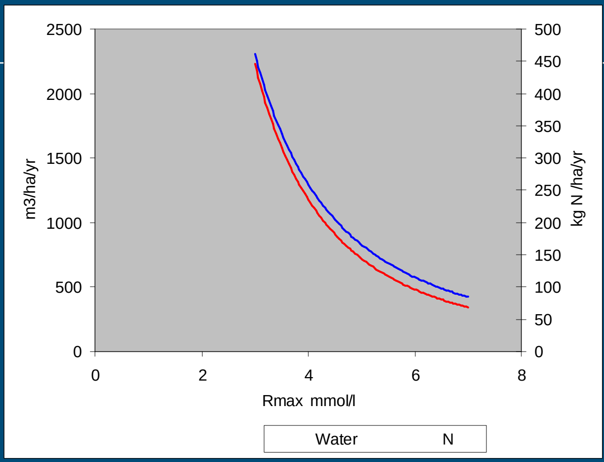
Simulations



Required discharge for rose as function of Rmax

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Maximize Na uptake / removal by crop

- Increase R_{max} (Na) to max acceptable level
- Change nutrient solution

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Margins for Na in the root environment

Tomato	EC	Na	NH4	K	Ca	Mg
Recommended	3.5	2	0.1	11	12.5	4.8
Rmax	3.5	6	0.1	9	10	4.3
Theoretically Rmax	3.5	17	0.1	5	6	3
Rose						
Recommended	1.8	2	0.1	5.5	5.5	2.4
Rmax	1.8	6	0.1	3.8	3.8	2.1
Theoretically Rmax	1.8	9	0.1	3	3	1.8

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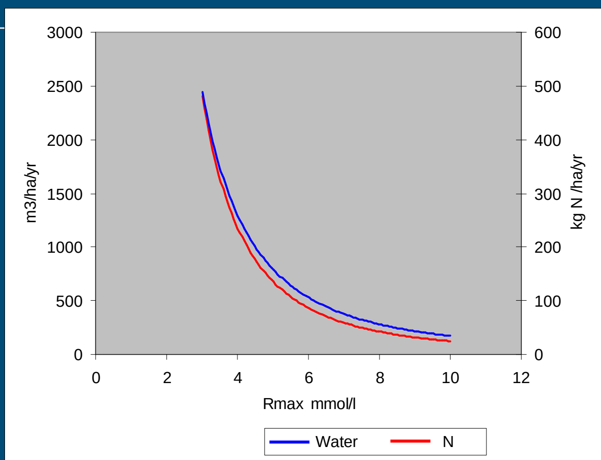
Simulations



Required discharge for rose as function of Rmax

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Discharge strategies

If R_{max} is reached, then:

- I Discharge volume drain collection tanks
  1- 4 times (depending on Na level)
- II Continuously x % discharge, during tap water input
  x depends on Na level
- III "Smart" discharge: Quantity equivalent of daily Na accumulation
- IV Daily total drainage volume, during tap water input

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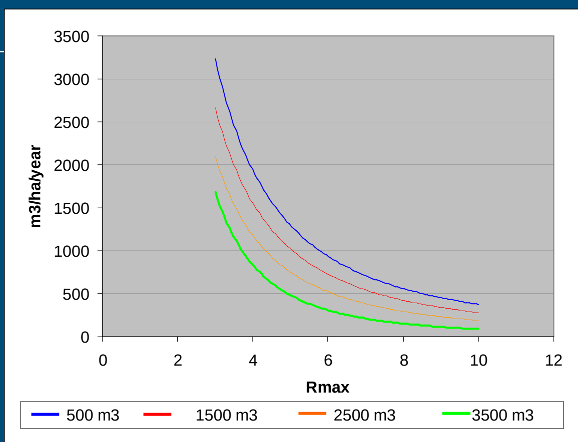
Simulations



Discharge volume as function of collection tank capacity and R_{max}

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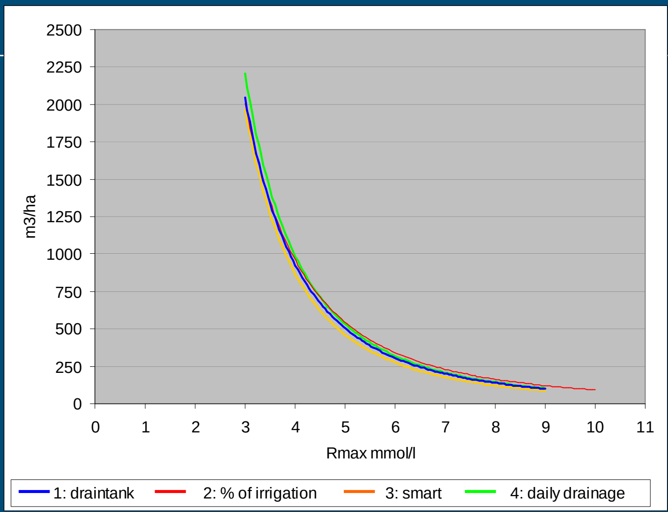

Discharge volume as function of Rmax, with four different discharge strategies *(3500 m3/ha collection tank)*

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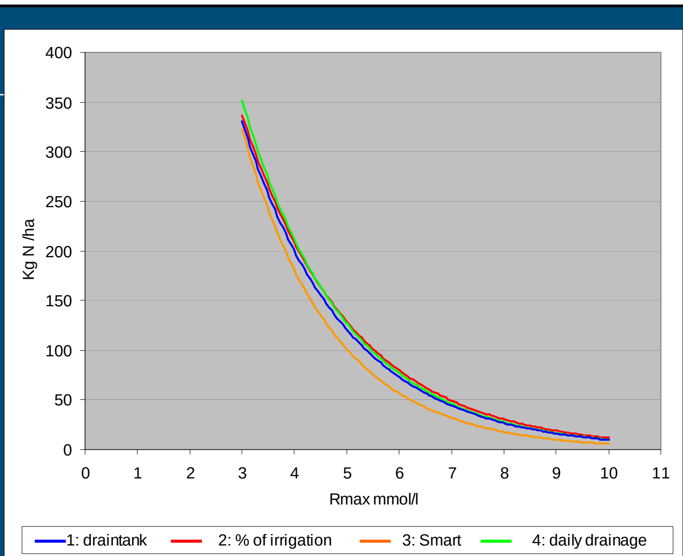

N quantity emission as function of Rmax, with four different discharge strategies *(3500 m3/ha collection tank)*

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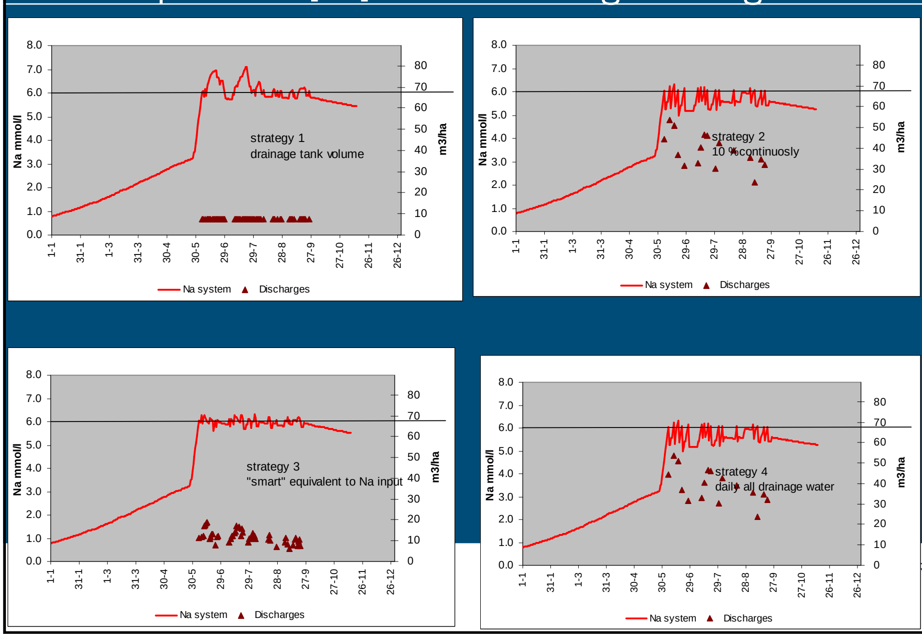
Development of [Na] with 4 discharge strategies



Conclusion

- *After resolving problems of growth reduction:*
  Salinity constraint for 0 emission target
  - Even with pure rainwater some crops
- Maximizing R_{max} most effective
  highest acceptable EC and lowest acceptable nutrient levels
- Discharge strategies not very different in total discharge
  “smart” disposal
  - reduce N emission 10 -15 %
  - More stable [Na]

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