Recent Trends in Salinity Control for Soilless Growing Systems Management

Nikolaos Katsoulas[1] and Wim Voogt[2]

[1]University of Thessaly,
Lab of Agricultural Constructions and Envir. Control

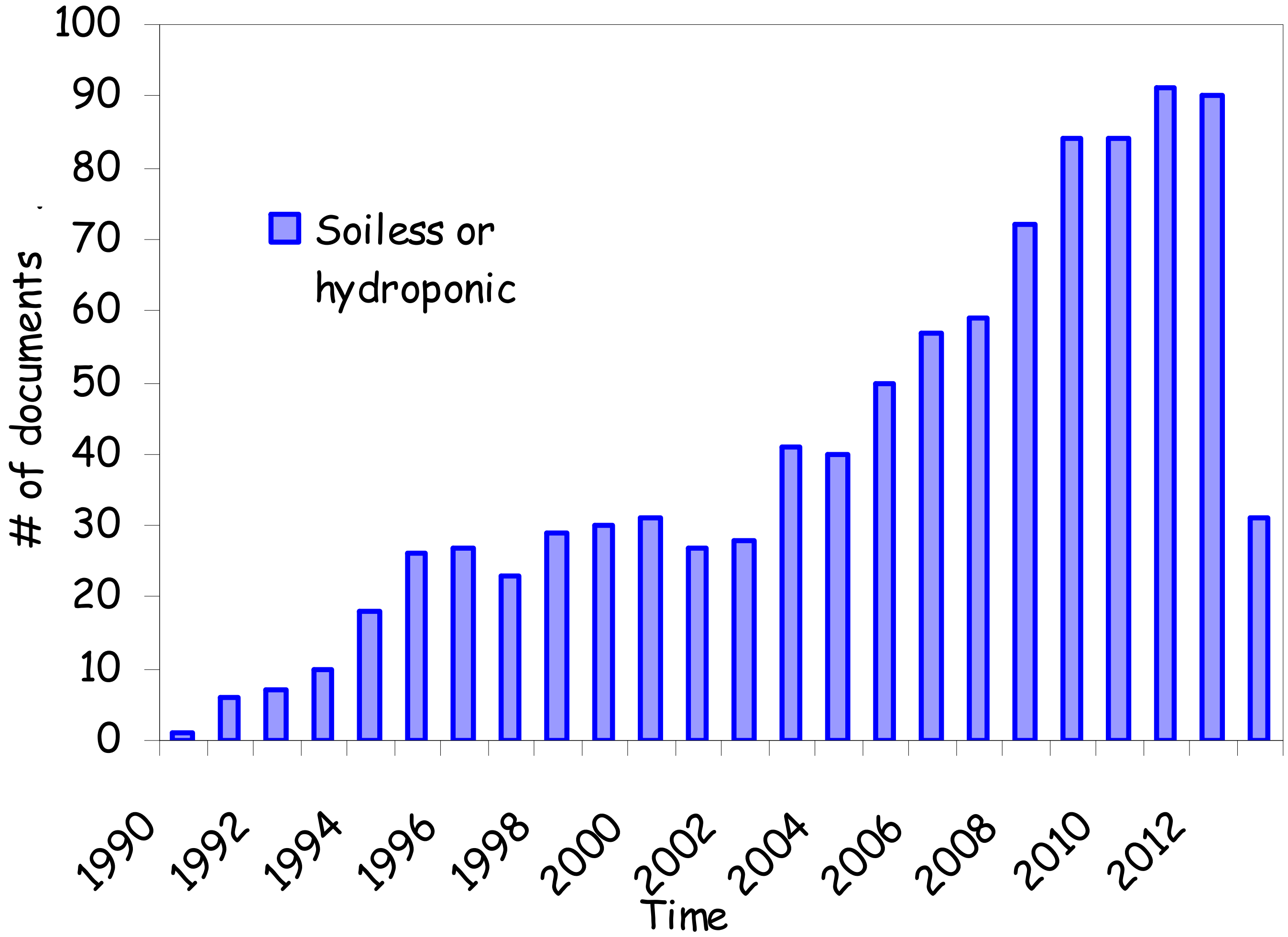
[2]Wageningen UR, Greenhouse Horticulture

Introduction

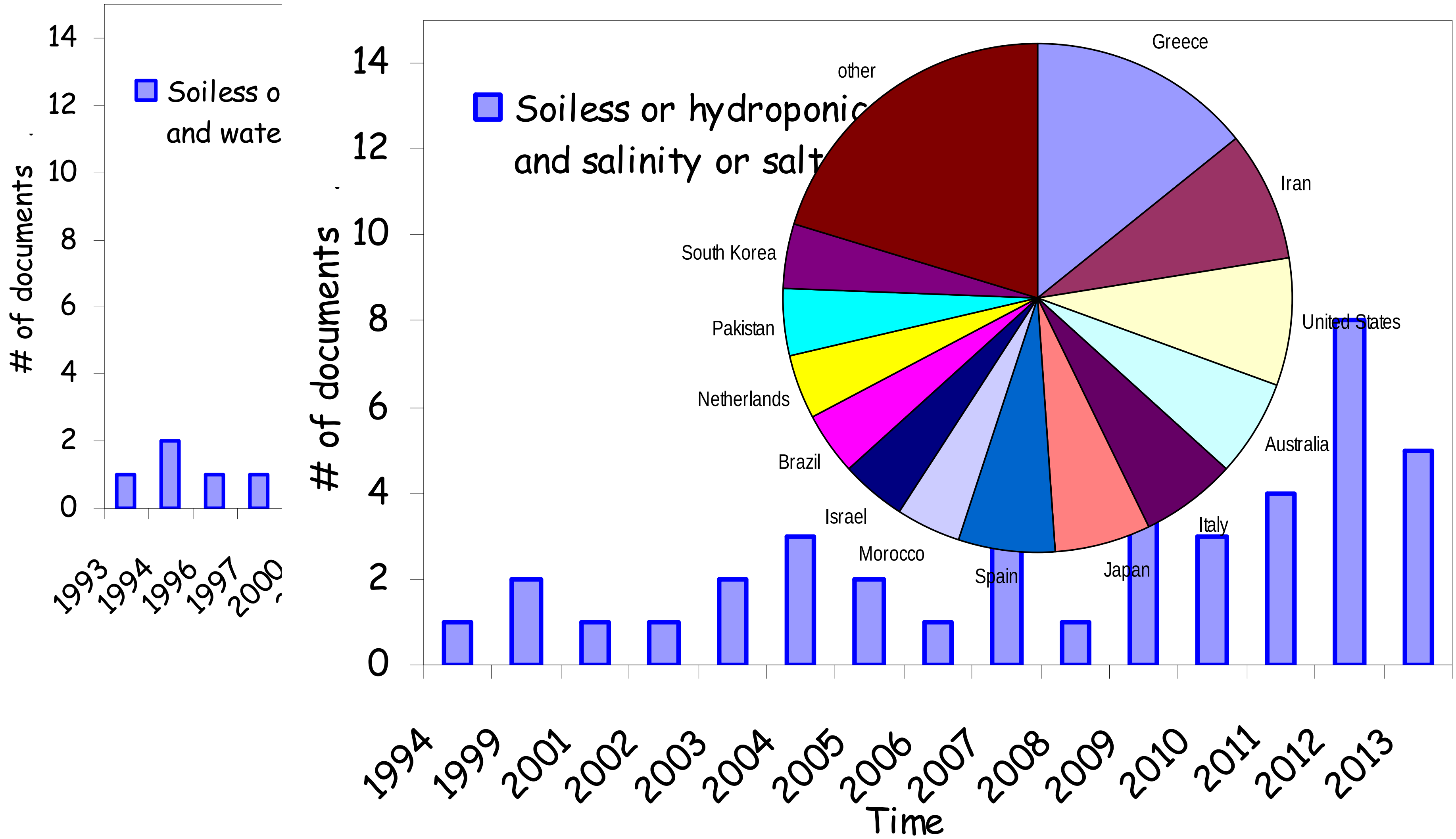
The three main causes behind the new trends in salinity control studies

- New constraints on greenhouse industry
  - Regulations aiming at reduction of leaching
  - Regulations on drainage discharge
  - Poor quality water
- New scientific approaches
  - Management through climate and irrigation control
  - Modeling of water and nutrients flow in the greenhouse
  - Sensor technology
- Needs for maximization of WUE

Current evolution of published research on "<u>soilless or hydroponic</u>"

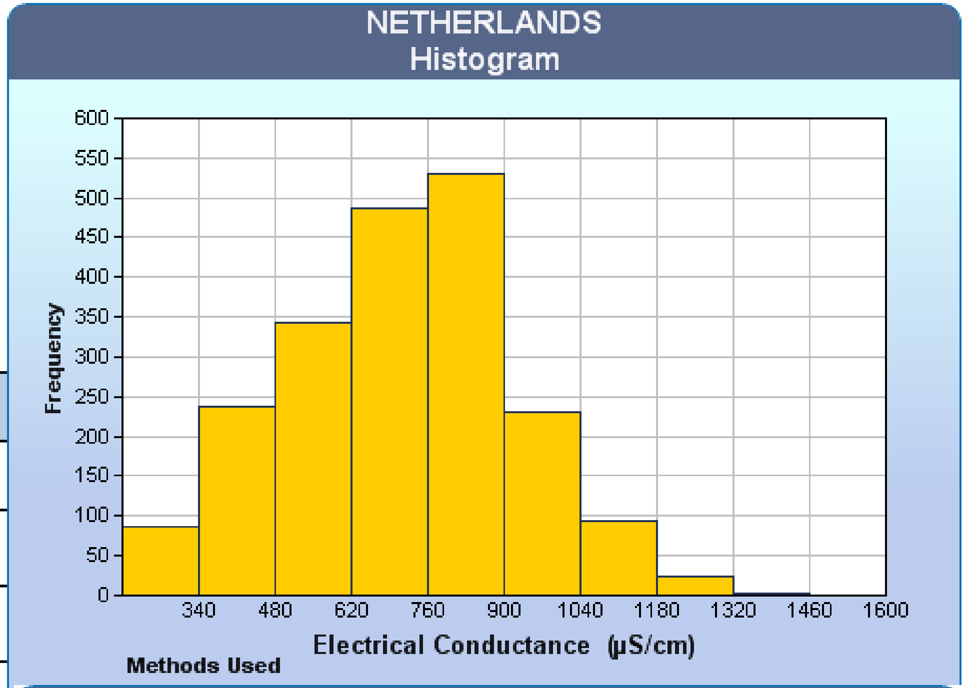


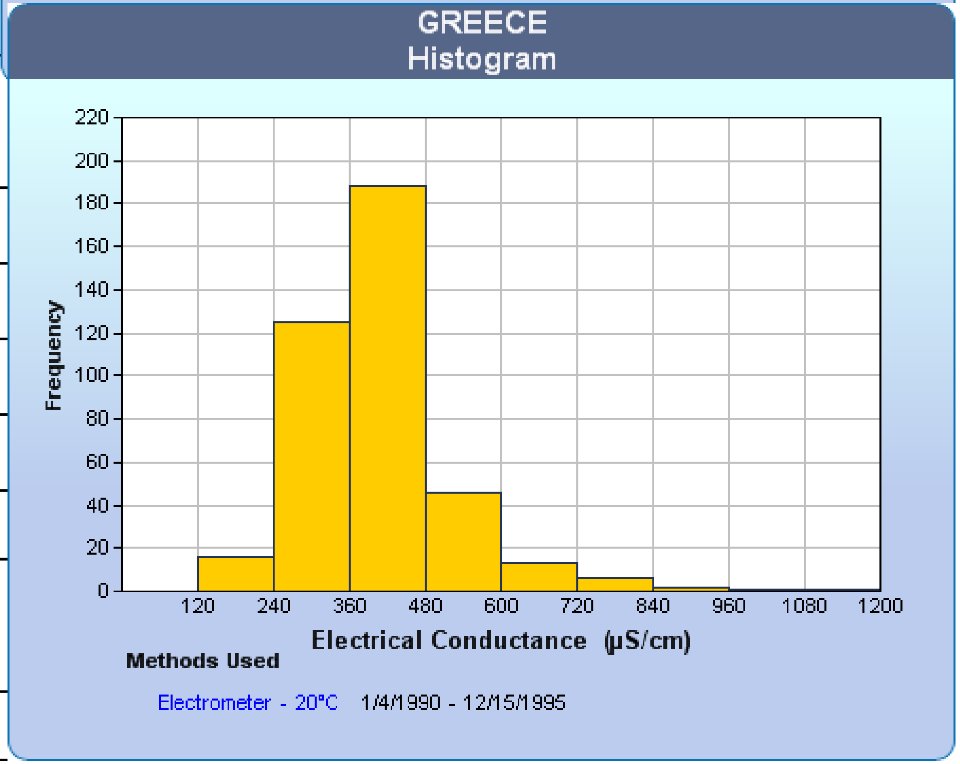
Current evolution of published research on …

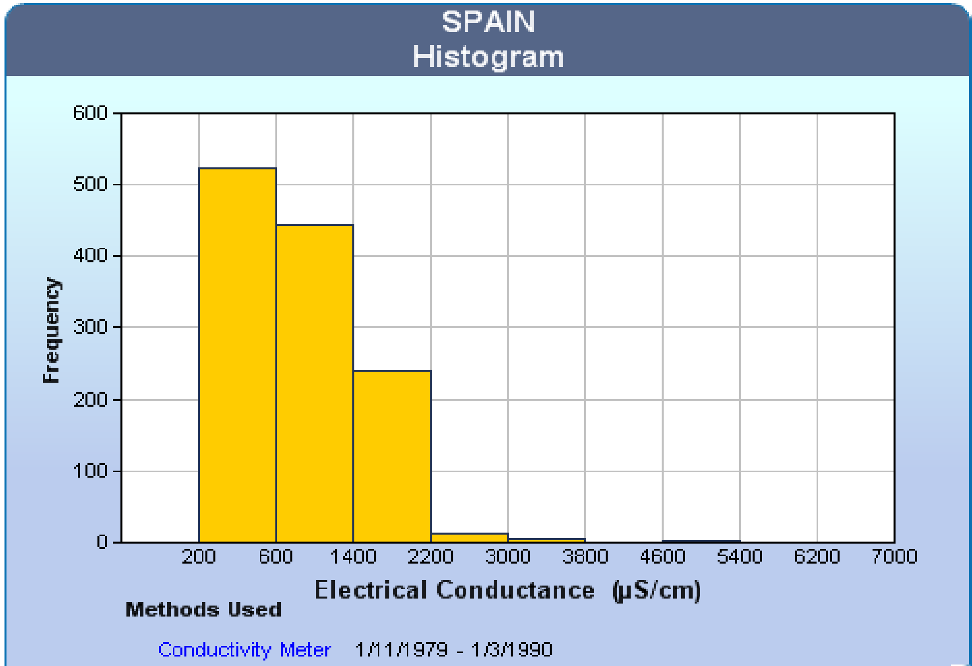


Water quality around the world

Area	Salinity Level
North Europe	<500 µS/cm
North-East Europe	500-1000 µS/cm
Central Europe	1000-2000 µS/cm
South Europe	500-1000 µS/cm
Central-South Africa	<500 µS/cm
North Asia	>2000 µS/cm
Central Asia	500-1000 µS/cm
West Asia	1000-2000 µS/cm
Australia	500-1000 µS/cm
North America	500-2000 µS/cm
Central-West America	500-1000 µS/cm
South America	500-2000 µS/cm






SPAIN
Histogram
Frequency
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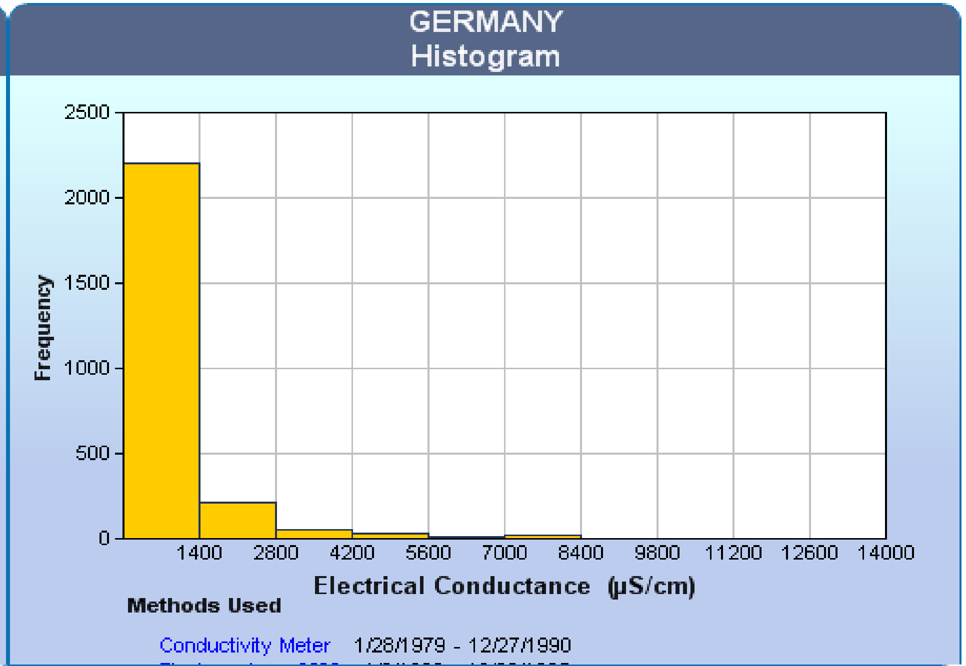
500
600
200
600
1400
2200
3000
3800
4600
5400
6200
7000
Electrical Conductance (µS/cm)
Methods Used
Conductivity Meter 1/11/1979 - 1/3/1990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Histogram
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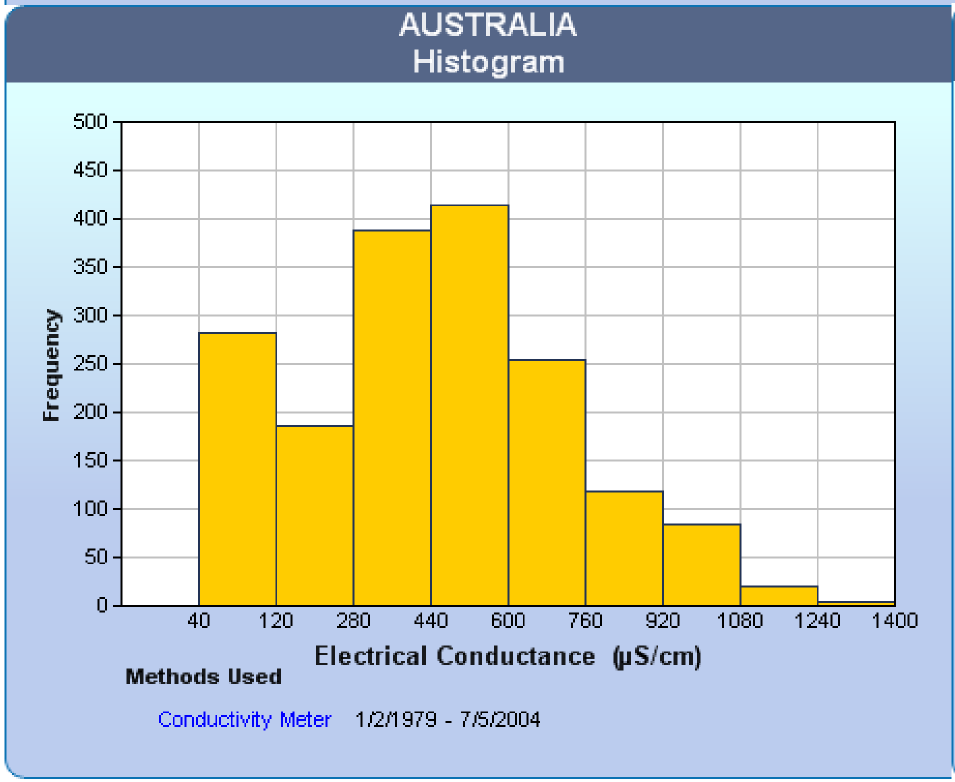
Electrical Conductance (µS/cm)
Methods Used
Conductivity Meter 1/28/1979 - 12/27/1990


AUSTRALIA
Histogram
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450
500
40
120
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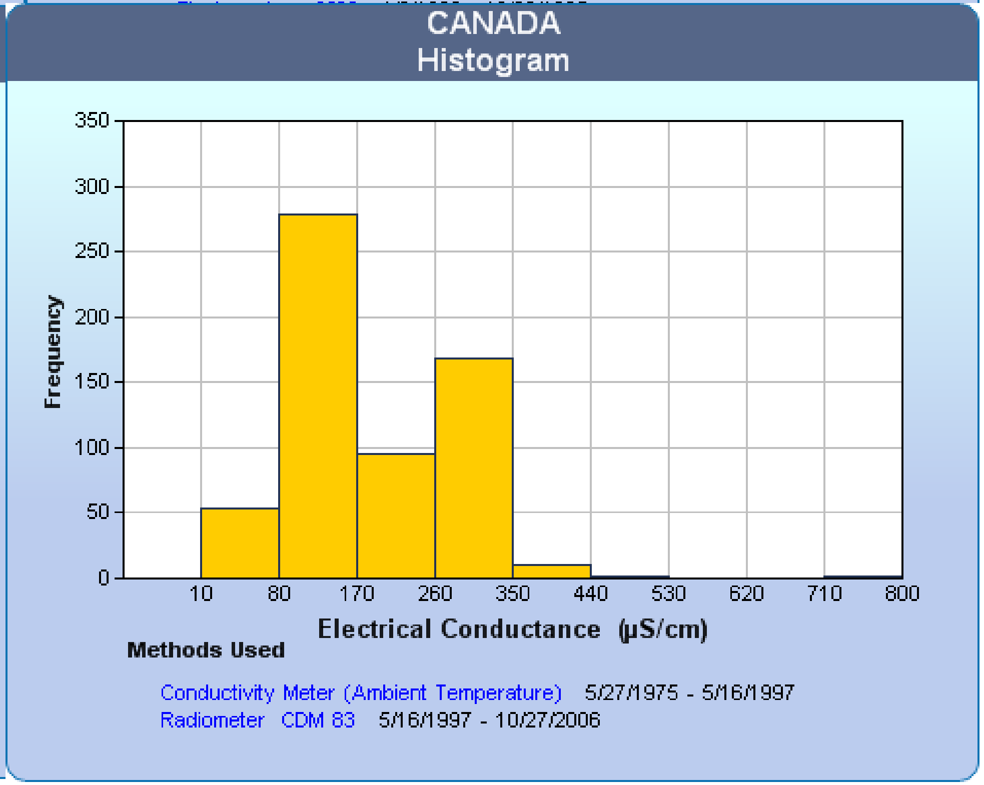
440
600
760
920
1080
1240
1400
Electrical Conductance (µS/cm)
Methods Used
Conductivity Meter 1/2/1979 - 7/5/2004


CANADA
Histogram
Frequency
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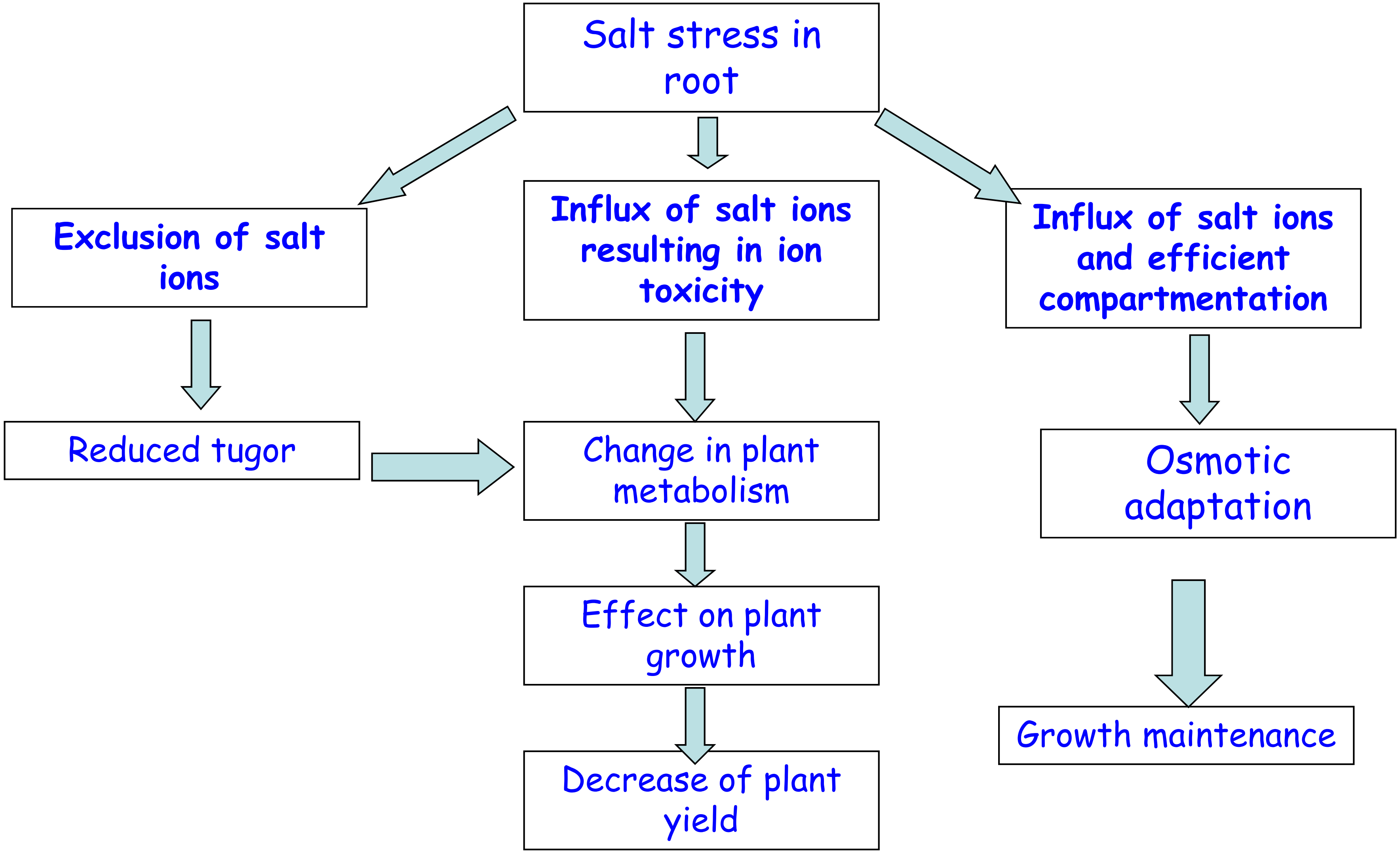
350
10
80
170
260
350
440
530
620
710
800
Electrical Conductance (µS/cm)
Methods Used
Conductivity Meter (Ambient Temperature) 5/27/1975 - 5/16/1997
Radiometer CDM 83 5/16/1997 - 10/27/2006

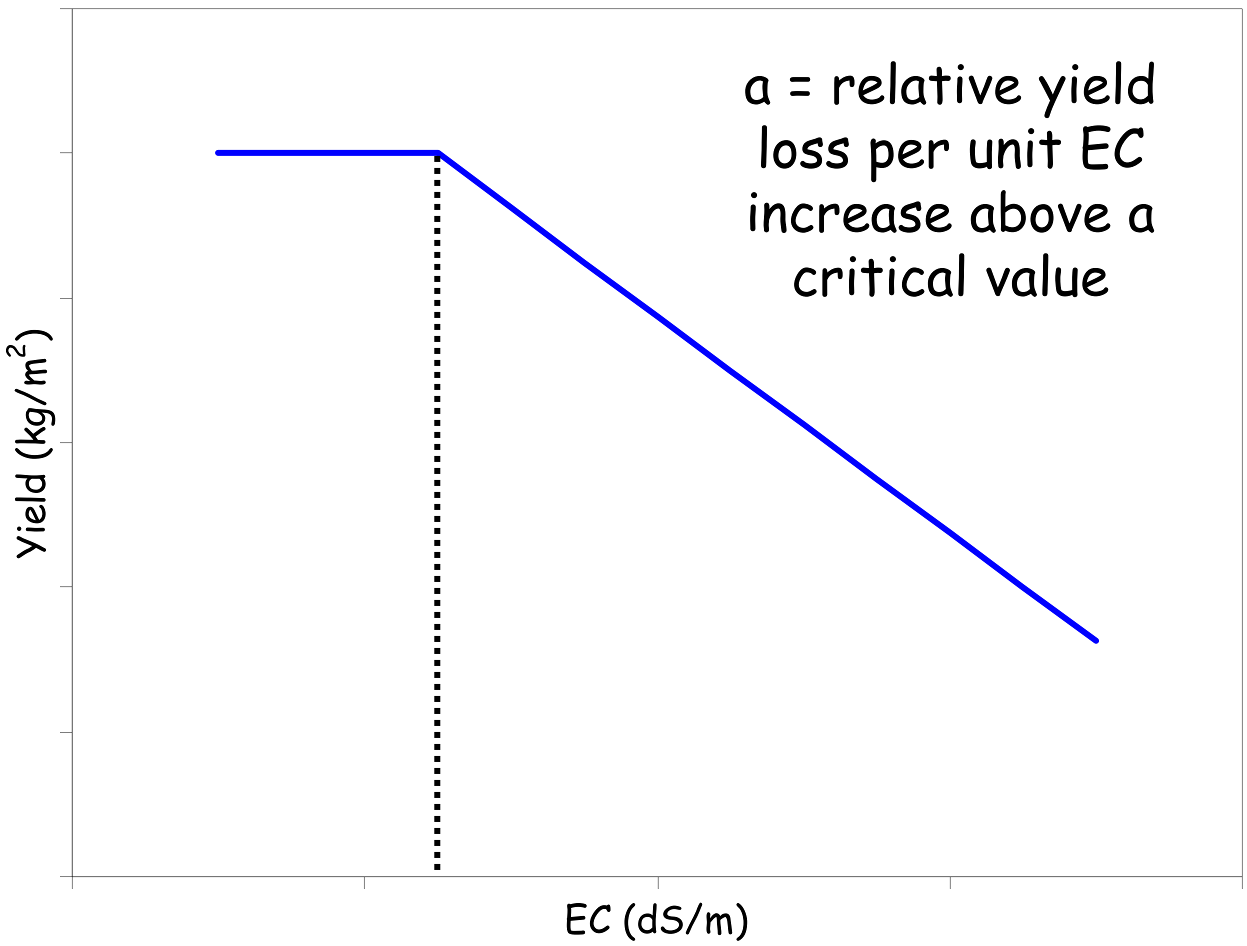
Review contents

1. **Effects of Salinity on Crop**
   - **yield**
   - **quality**
2. **Managing High Salinity**
   - **Irrigation**
   - **Fertilisation, K, Ca uptake**
   - **Greenhouse climate:** Radiation, CO_2, VPD
   - **Crop:** differences in Na uptake concentrations
3. **Alternatives to overcome Salt Accumulation-Practical Management**
   - **Desalination**
   - **Dealing with salinity**
   - **Control**
   - **Others**
4. **Future Perspectives**

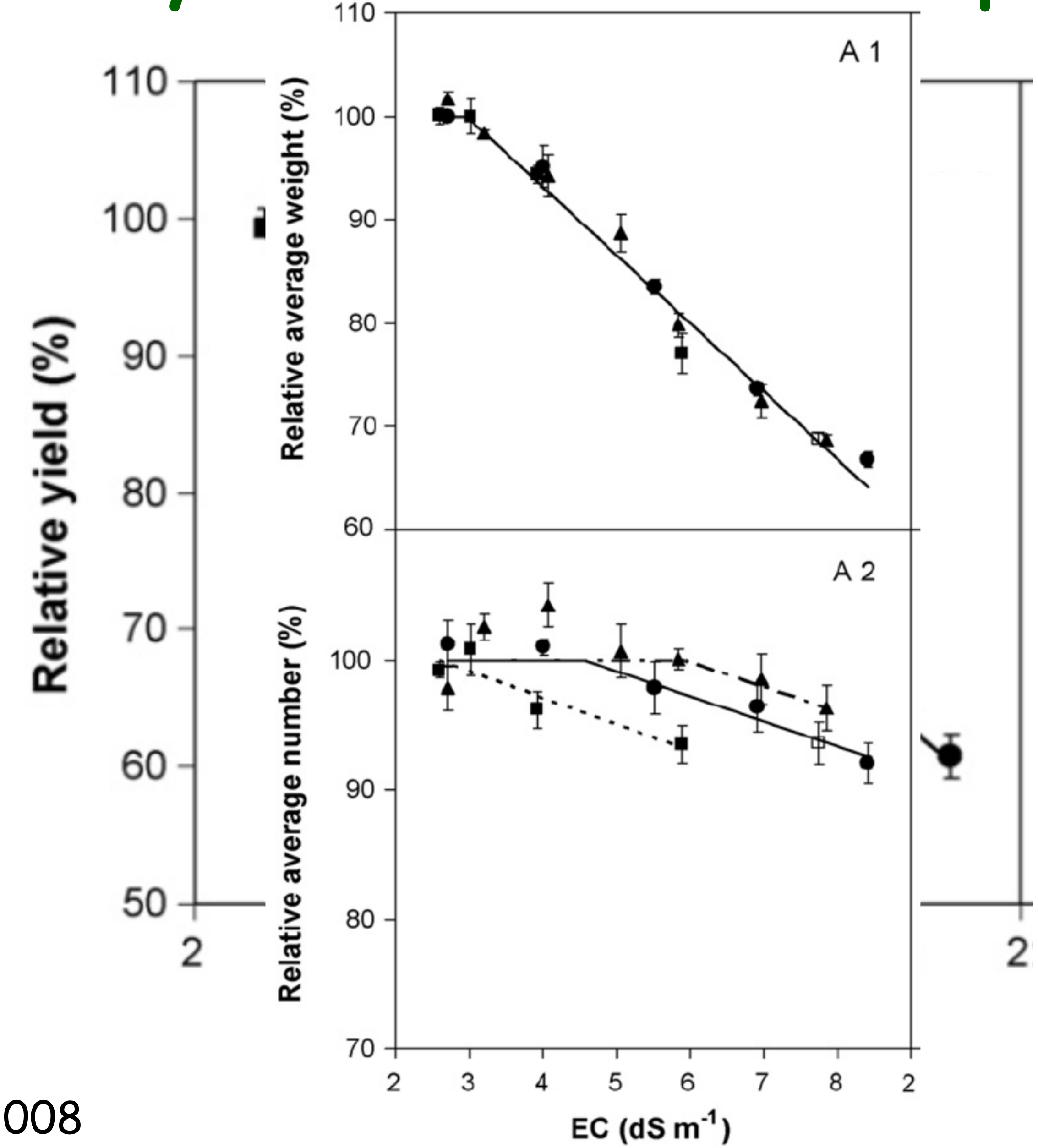
The mechanism- time depended effects



Salinity effects on crop yield



Salinity effects on crop yield

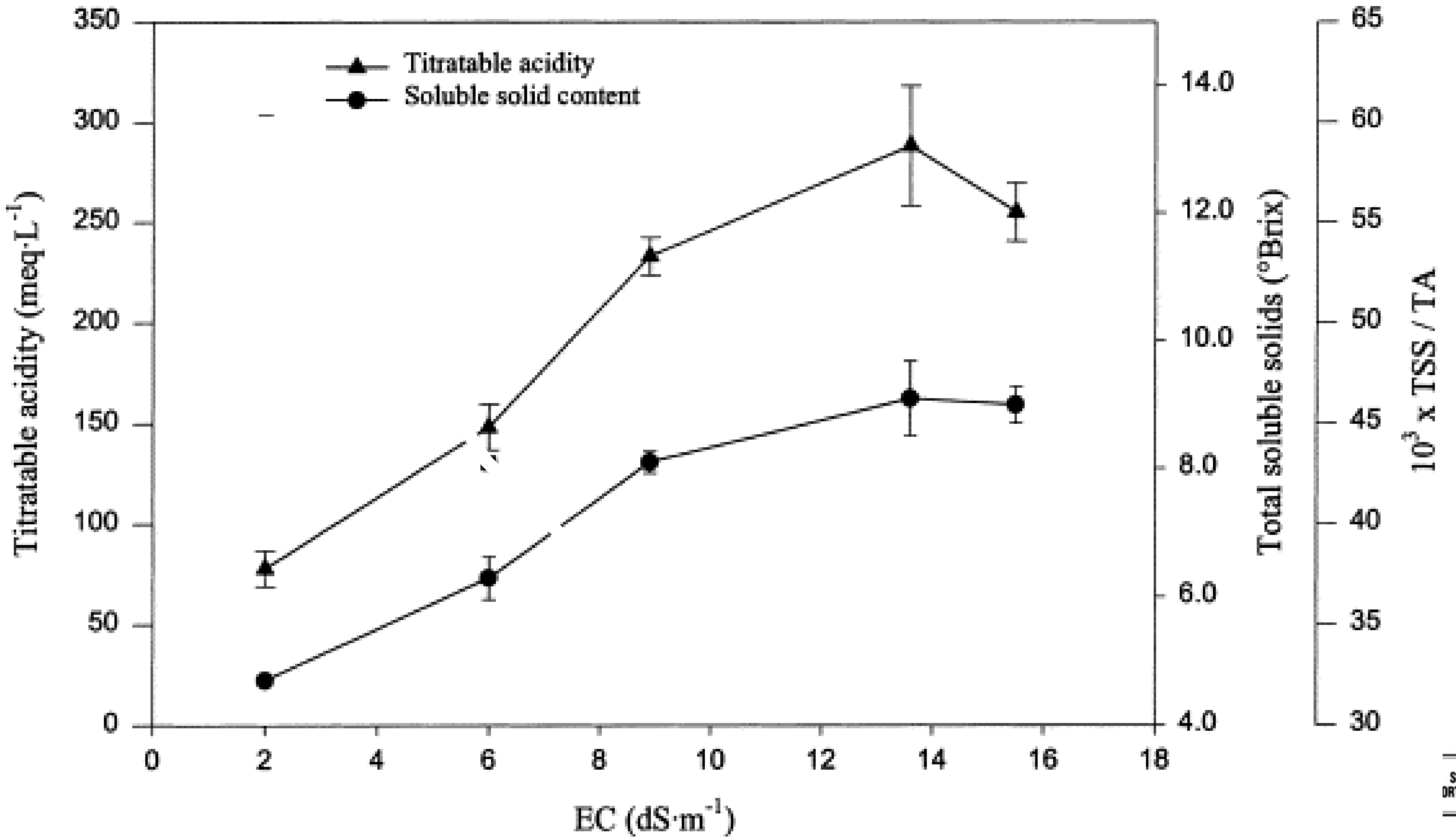


tomato

Magan et al., 2008


Effects of salinity on fruit yield and quality of tomato grown in soil-less culture in greenhouses in Mediterranean climatic conditions

Salinity effects on product quality



SCIENTIA HORTICULTURÆ

Tomato and salinity

Jesús Cuartero*, Rafael Fernández-Muñoz

Estación Experimental La Mayora – CSIC, 29750, Algarrobo-Costa, Málaga, Spain

Cuartero and Fernandez-Munoz, 1999

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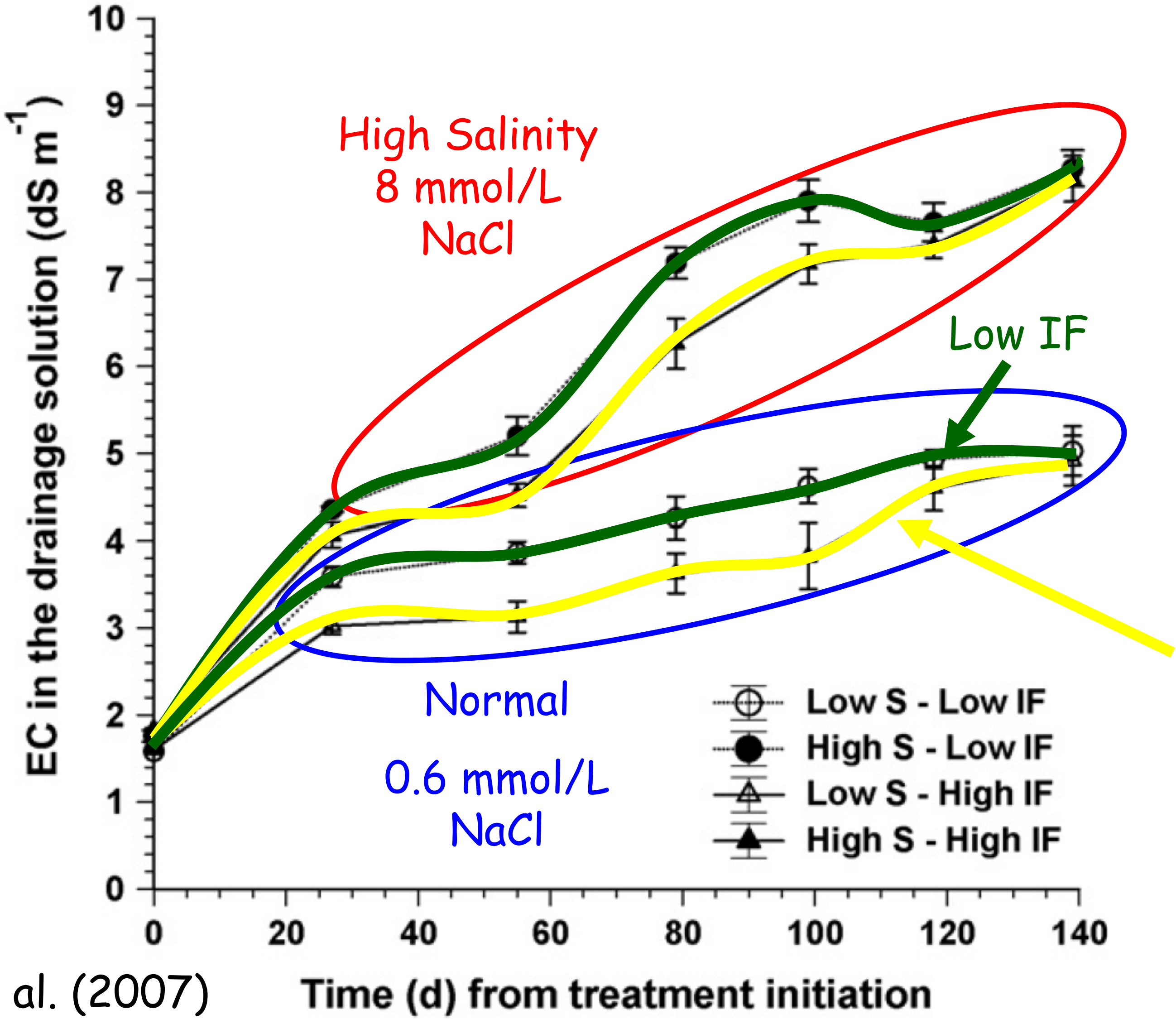
Interactions between Salinity and Irrigation Frequency (IF)



Higher IF

Lower EC

Lower Na^+ and Cl^-

Savvas et al. (2007)

Interactions between salinity and fertilisation

Salt accumulation in closed systems requires that competitive uptake phenomena (e.g. Na-K and Cl-NO_3) and osmotic potential effects on water uptake and nutrients mass flow to roots be accounted for fertilisation needs estimation.

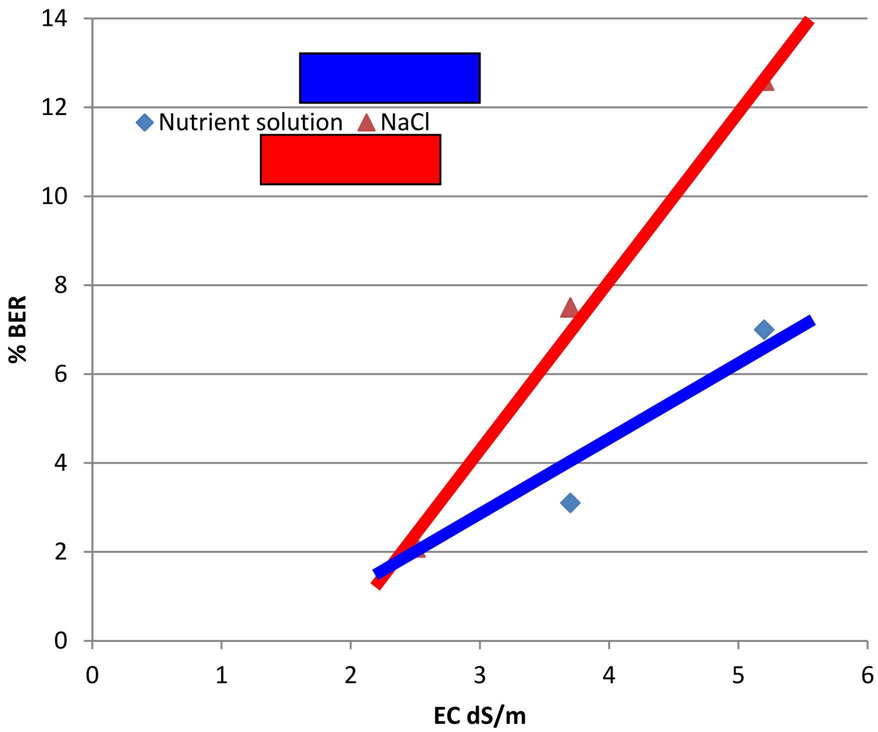
Savvas and Lenz (2000) found that fresh fruit yield of *eggplant* was significantly reduced to the same extent independently of the source of salinity (extra nutrients or 25 mmol L^{-1} NaCl).

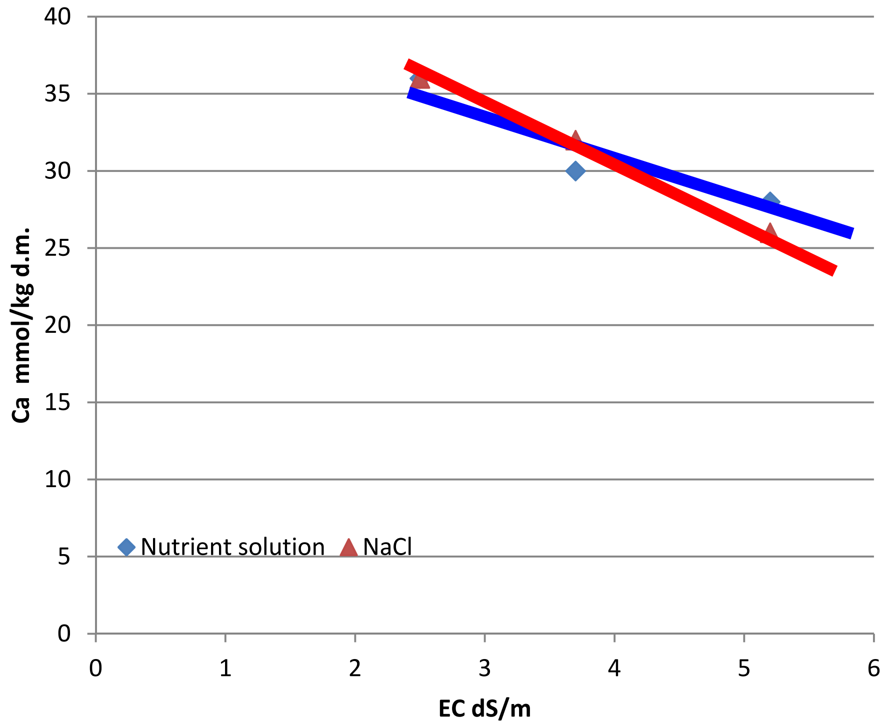
Interaction between salinity and nutrients

Element	EC value (µS/cm)		
	0.75	2.5	5.0
K	658	953	1080
Ca	858	794	587
Mg	274	161	160

Cation content (mmol kg^{-1} dry matter) of laminae of tomato as affected by different EC values at equal ratios of nutrients.
After Sonneveld and Voogt, 1990.

Interaction between salinity and nutrients





Blossom en rot and Ca in fruits for sweet pepper,
as affected by EC increase due to nutrients only or NaCl.
After Sonneveld and van den Burg (1991)

Climate control

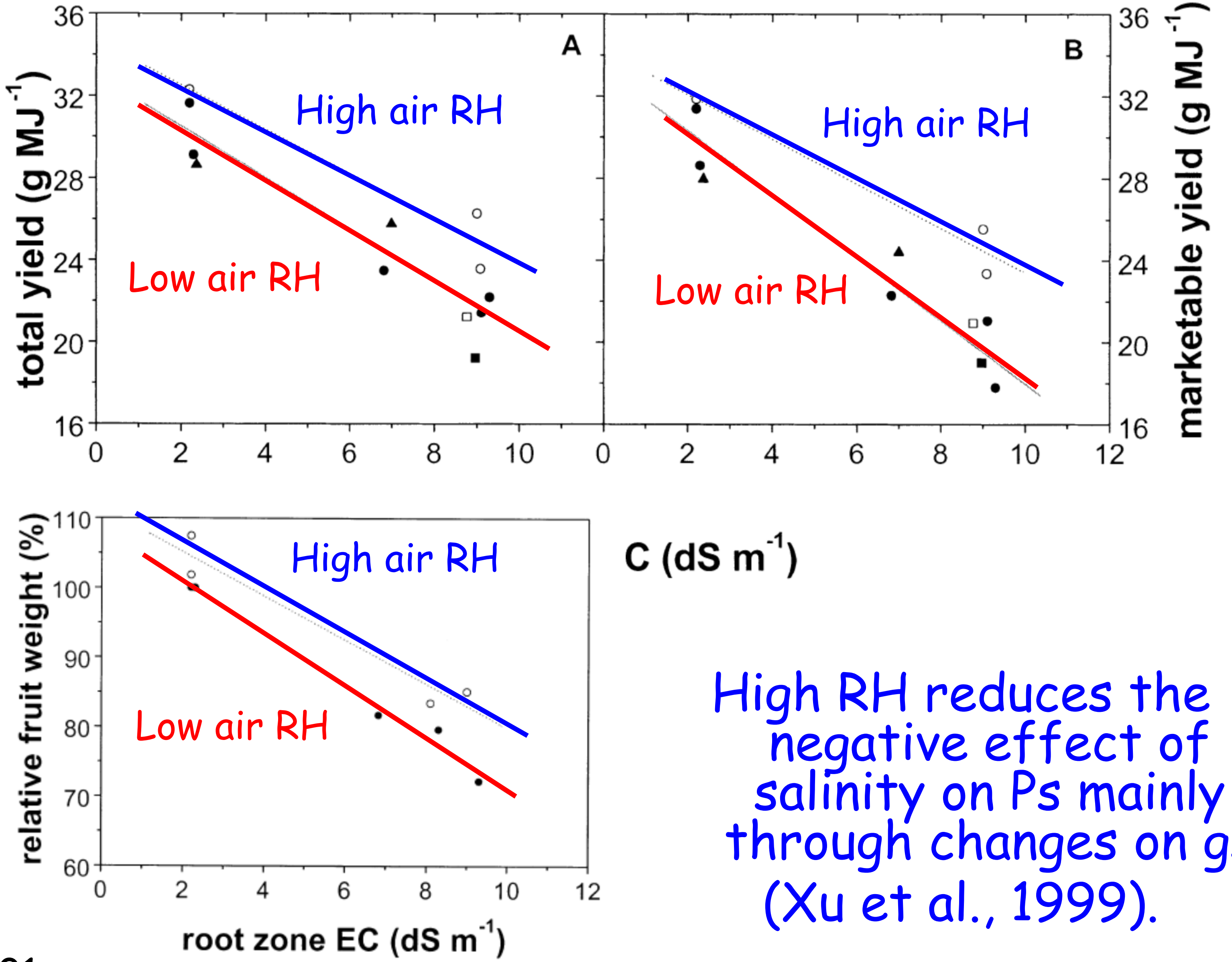
The mechanism involved

- *High relative humidity, low solar radiation*

Decrease in VPD → Decrease in plant-root water flow → Reduced upward transport of Na^+ via the xylem to plant leaves (An et al., 2001) → Growth promotion

Romero-Aranda et al. (2002) found that misting the greenhouse reduced root water uptake by plants grown under salinity or normal conditions by 15% and 40%, respectively.

Effect of air relative humidity



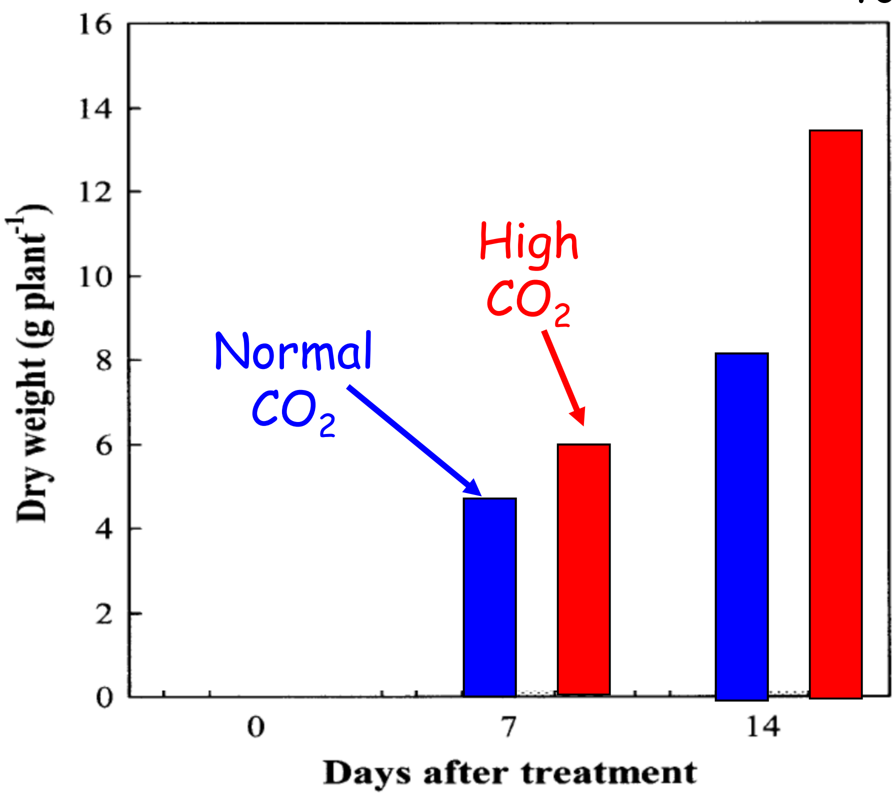
Li et al., 2001

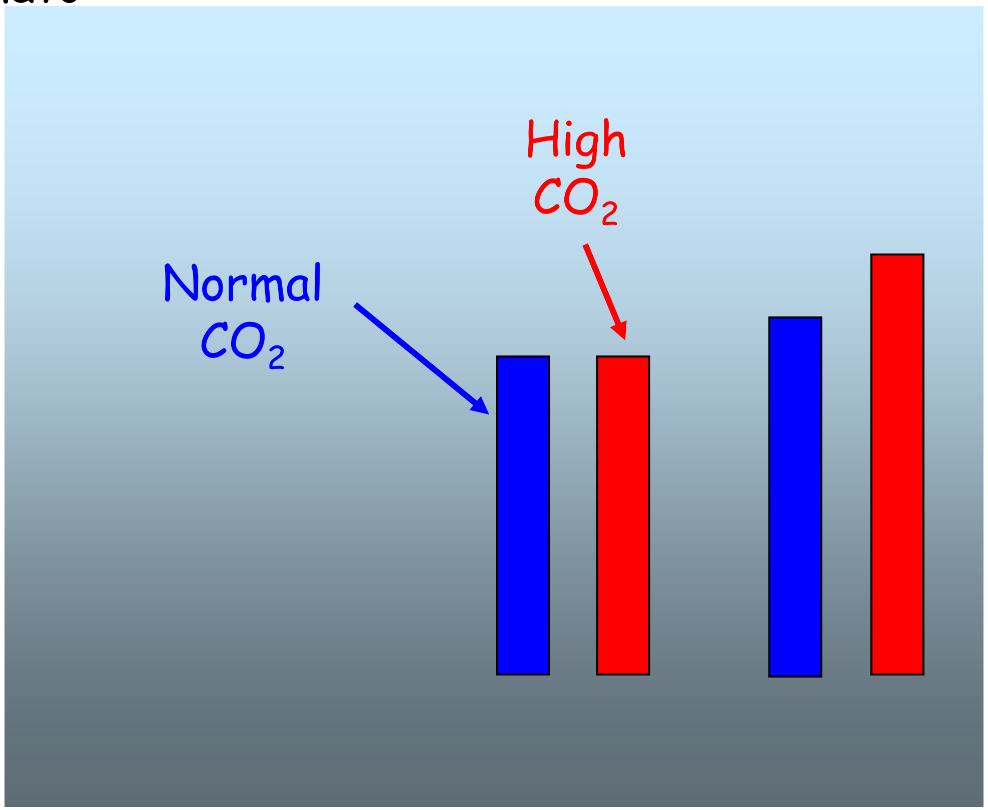
High RH reduces the negative effect of salinity on Ps mainly through changes on gs (Xu et al., 1999).

Interactions between salinity and CO_2 concentration

Takagi et al., (2009).

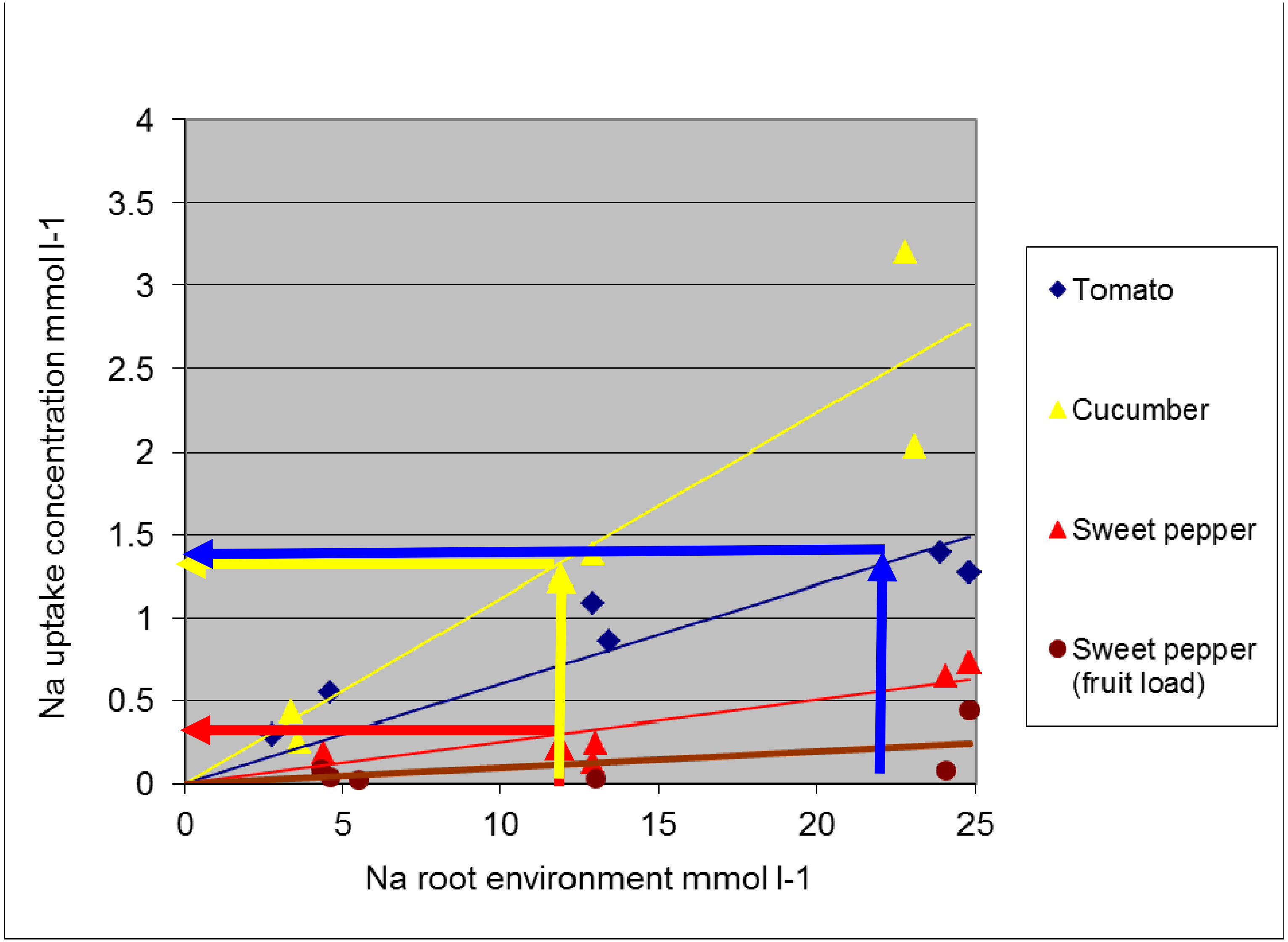
tomato





The increase in external CO_2 levels compensates for the decrease in stomatal conductance with respect to the CO_2 diffusion rates through stomata.

Crop differences in Na^+ uptake concentration- chance to use different crops



Voogt et al. (2012)

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Desalination

- Desalination technologies do exist but it's a matter of cost if and when we have to apply them.
- Hydroponics/ (semi-) closed soilless system will help to make des. more economically feasible
- Mix of rain water, surface water or water from any other source to delay salt accumulation.

Desalination-when? Economical point of view

$$Y = \text{gross return under optimal conditions}$$

Gross return under salinity = $Y(1 - aEC)$

Water consumption = $\frac{EC - 0.5EC_{in}}{aY} = ETP\exp(-bEC_{in})$

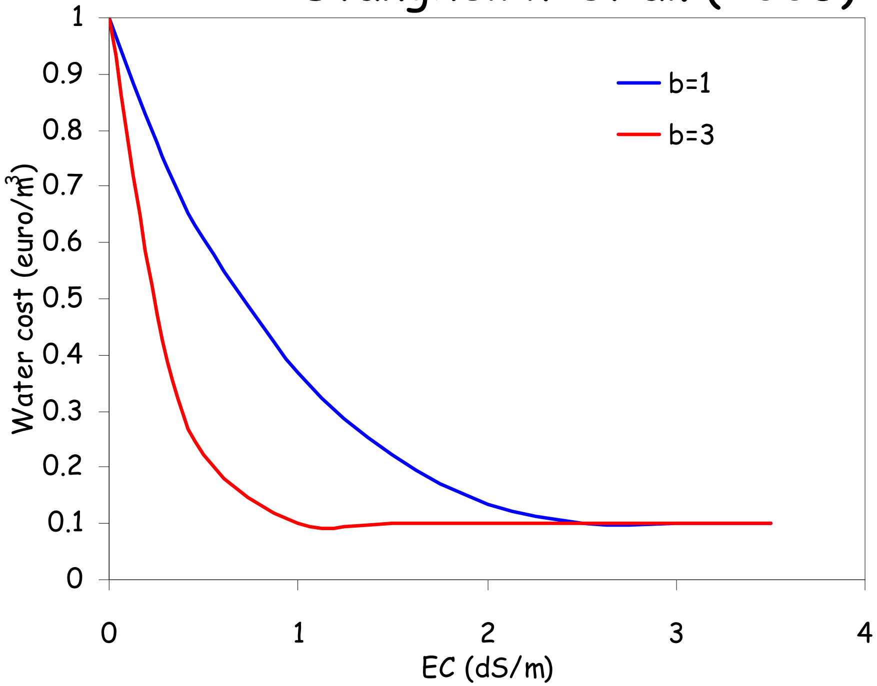
water price = P

$$k = \frac{EC - EC_{in}}{P\,ETP}$$

$$Y(1 - aEC) - \frac{EC - 0.5EC_{in}}{EC - EC_{in}} P\,ETP$$

$$EC_{in,optimal} \approx \frac{0.5}{k} = 0.$$

Stanghellini et al. (2005)



Dealing with Salinity

- Open or semi-closed: economize drainage fraction
  - Use drainage for other purposes/crops
  - Cascade solution
- Closed systems: discharge
- Optimise nutrient solution (basic input, analysis, adjustments in time)
- Maximise the acceptable accumulation for Na^+ / Cl^- / SO_4^{--} … by depleting the concentrations of nutrients to lowest acceptable minima

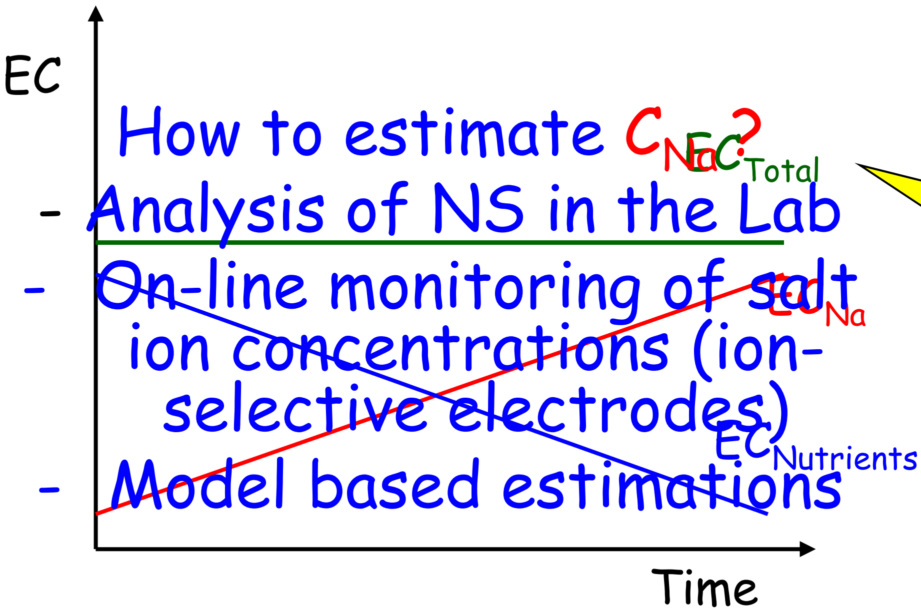
Standard methods for NS recirculation

- preparation of a nutrient solution with a composition corresponding to the estimated nutrient to water uptake ratios (de Kreij et al. 1999)
- the NS is blended with the DS to be recycled.

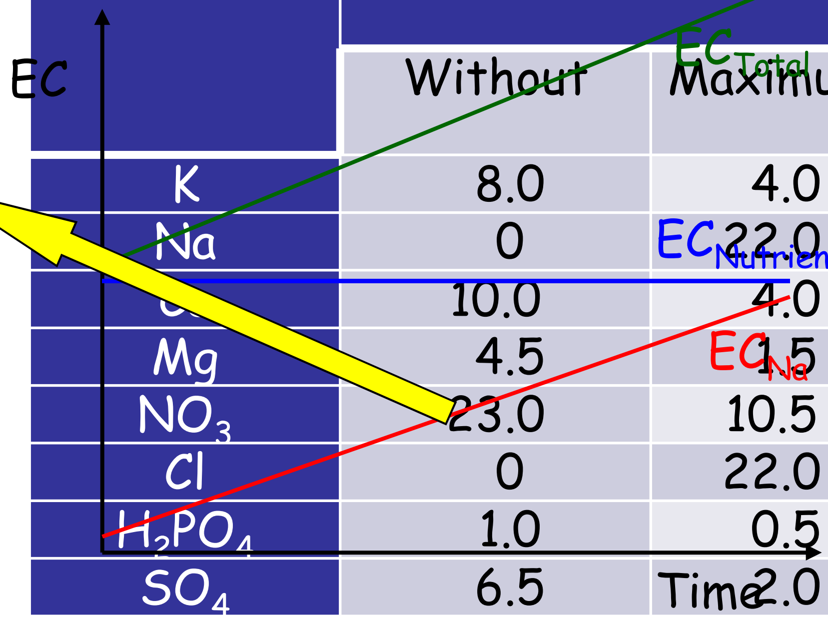
Mixing strategies

How to estimate C_{Na}?

- Analysis of NS in the Lab
- On-line monitoring of salt ion concentrations (ion-selective electrodes)
- Model based estimations



Elements	Accumulation of NaCL	
	Without	Maximum
K	8.0	4.0
Na	0	22.0
Ca	10.0	4.0
Mg	4.5	1.5
NO_3	23.0	10.5
Cl	0	22.0
H_2PO_4	1.0	0.5
SO_4	6.5	2.0



How to estimate C_{Na}?

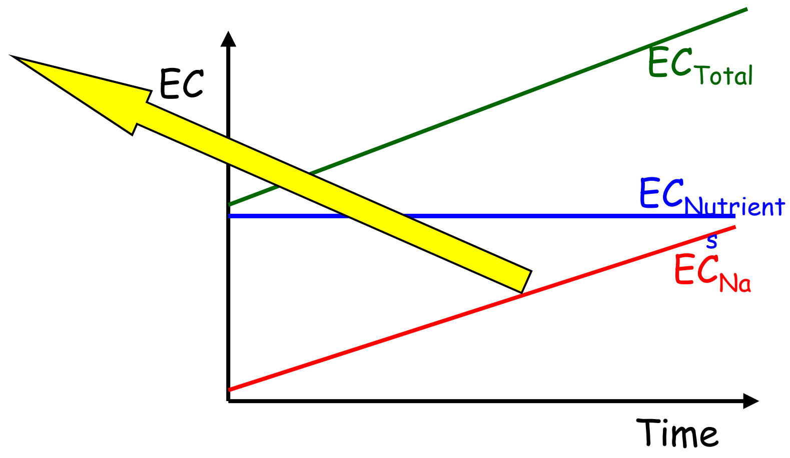
On-line monitoring of salt ion concentrations (ion-selective electrodes)

.

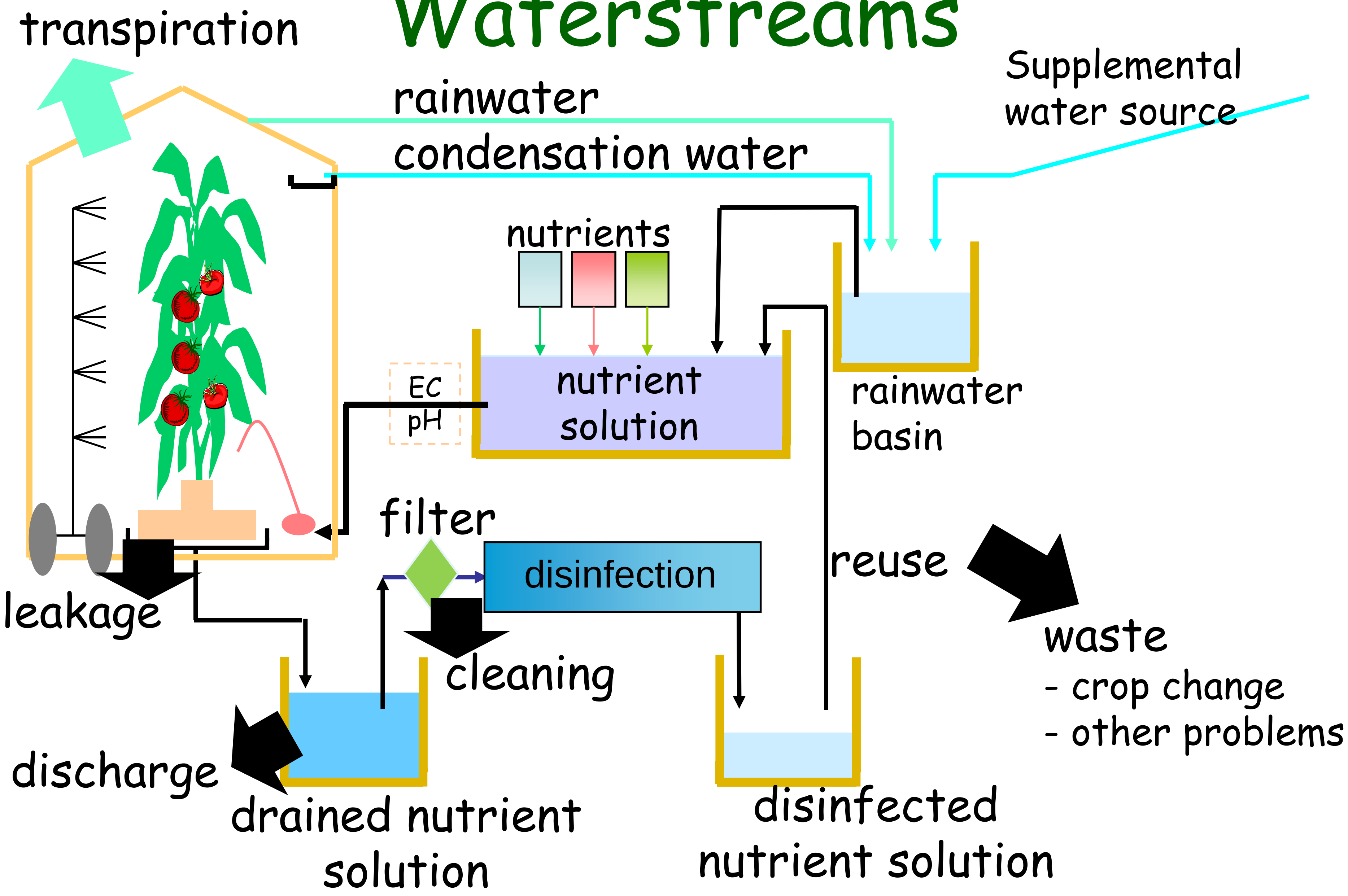
Attractive for practical applications as it allows the use of small size sensor, low cost i real time.

However, there are practical limitations:

- min, max time needed/allowed in the solution
- regular calibration
- special attention to maintenance
- accuracy



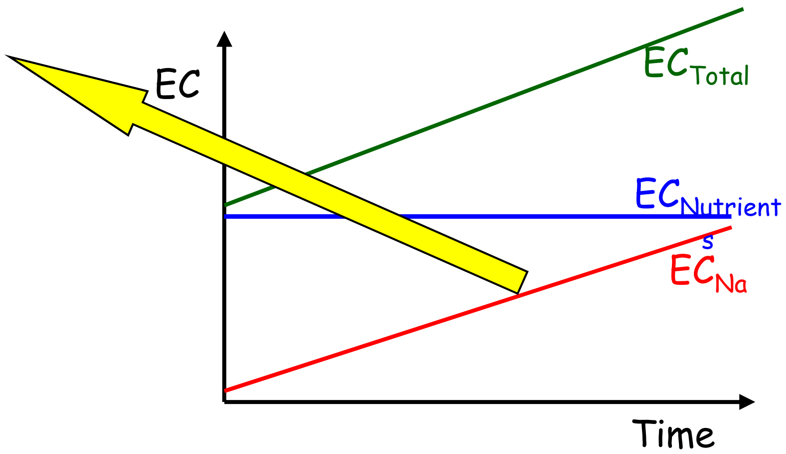
Waterstreams



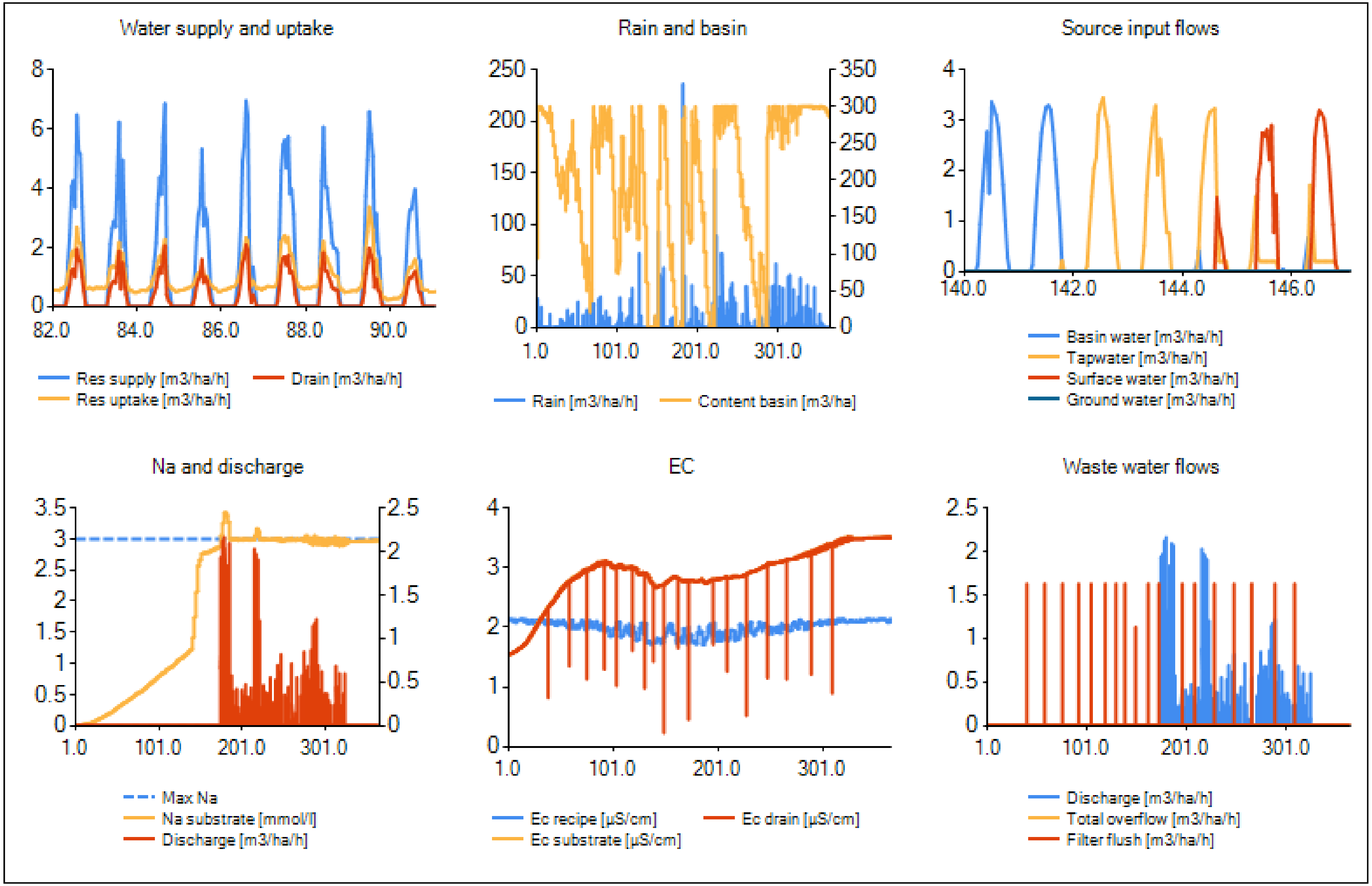
How to estimate C_{Na}?

Model based estimations

- Kempkes and Stanghellini (2003)
- Carmassi et al. (2003)
- Savvas et al. (2005)
- Voogt et al. (2012)

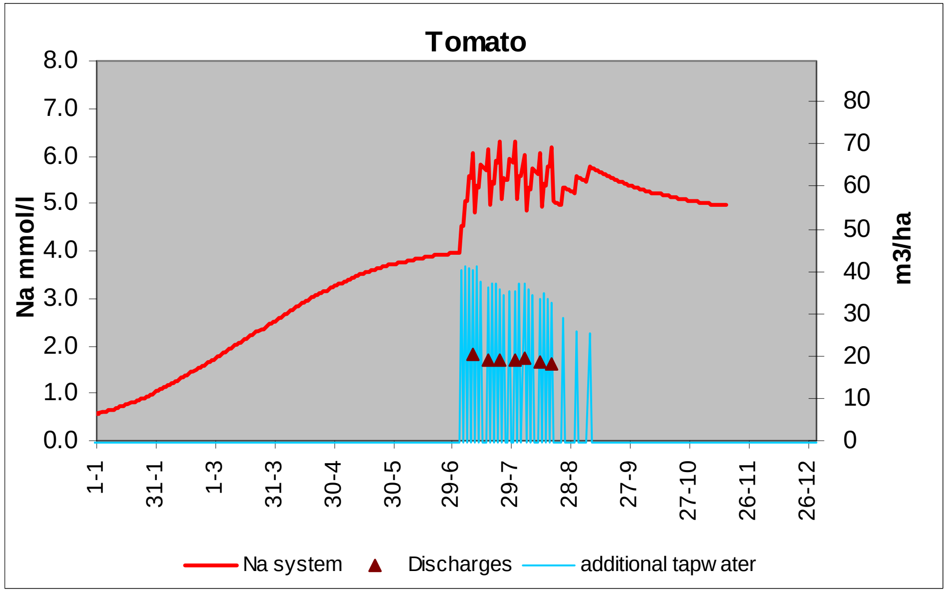


Simulation results

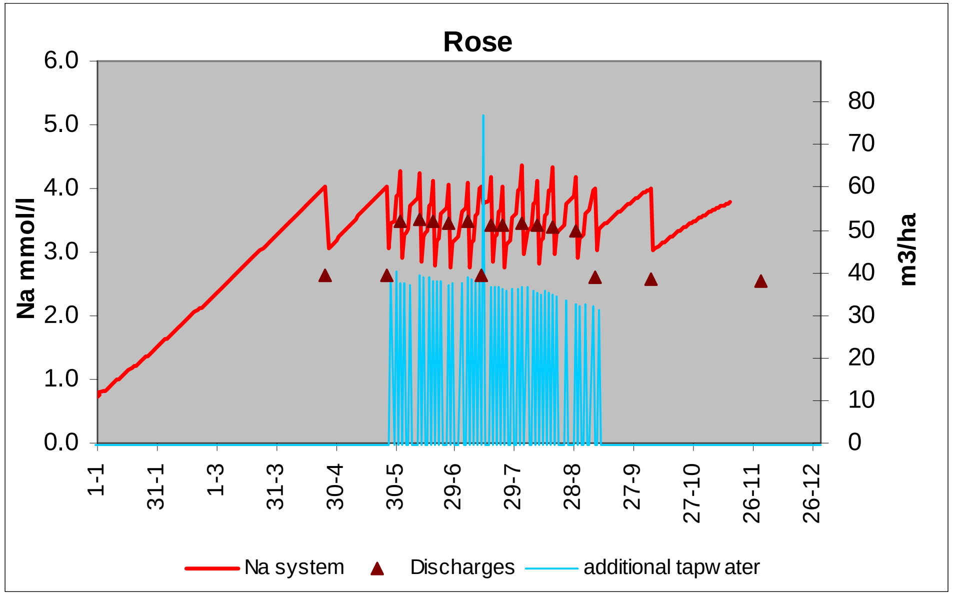


Waterstreams

2 % discharge needed
(54 kg N/ha)



10 % discharge needed
(240 kg N/ha)



- Useful tool for :
  - Policy makers
  - Greenhouse design
  - Project development
  - Scenario studies
- Evaluate various water sources
- Estimation of discharge / emissions

DSS for on-line control of [Na^+]

A decision-support-system for management of the drainage water in semi-closed hydroponic systems was developed (Katsoulas et al., 2012, 2013).

The system is based on:

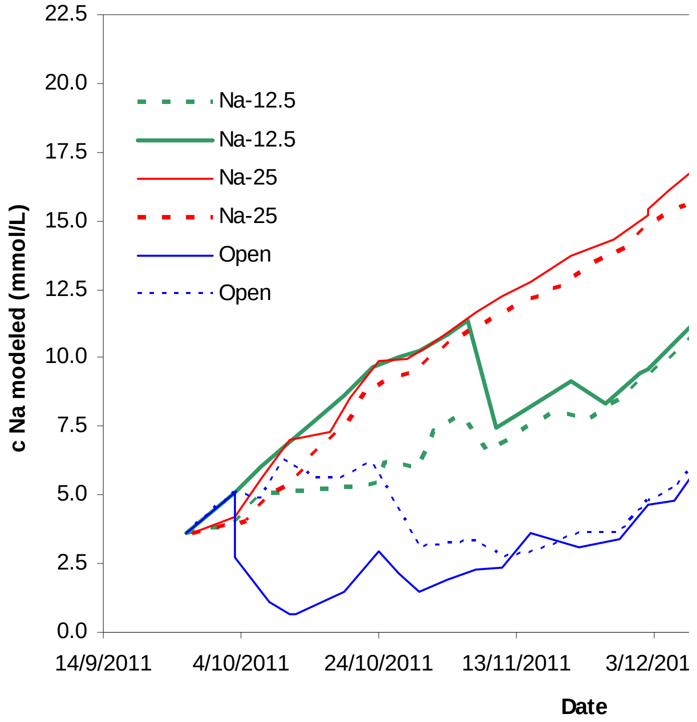
- Na^+ mass-balance model (Savvas et al., 2007; 2008; Varlagas et al., 2010) and
- measurements of water flow in the system

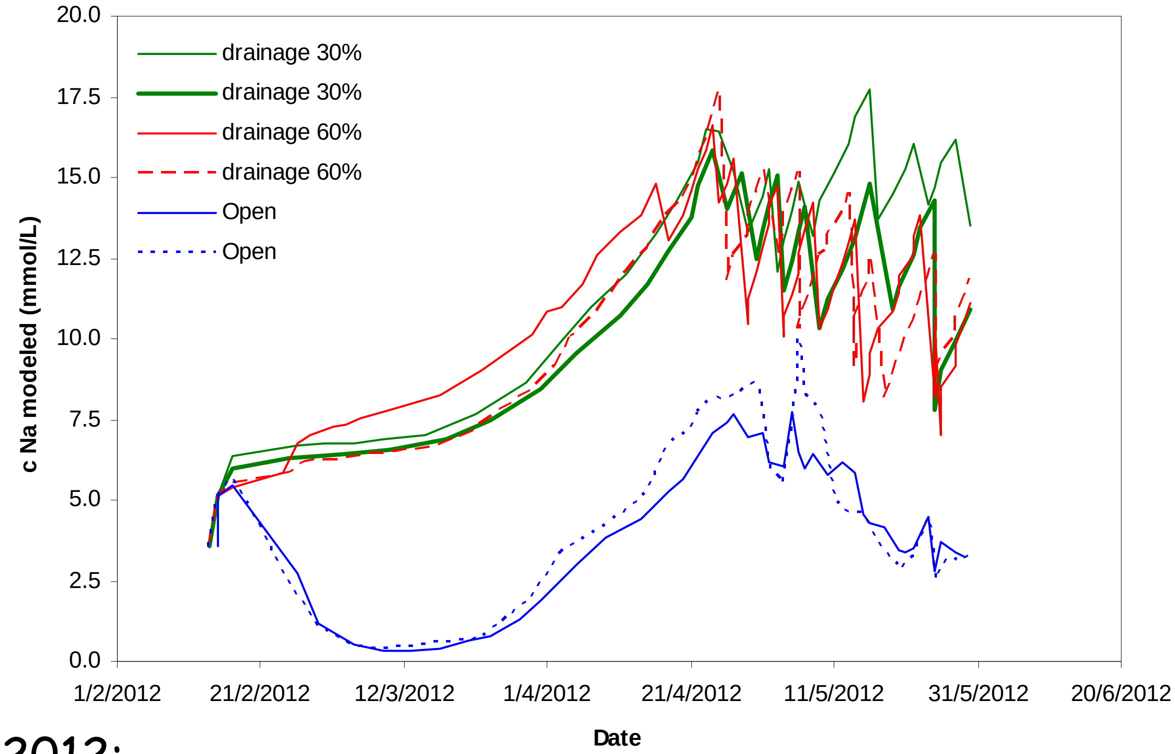
Kittas et al., 2013. Key on-farm irrigation techniques to save water. Sustainable use of irrigation water in the Mediterranean Region (Sirrimed). Project report. WP1.

System performance

Period 1, September 2011 – January 2012:

1- **open system**.
2- **semi-closed** system, recirculation in order to maintain **[Na+] < 12.5** mmol/L
3- **semi-closed** system, recirculation in order to maintain **[Na+] < 25** mmol/L

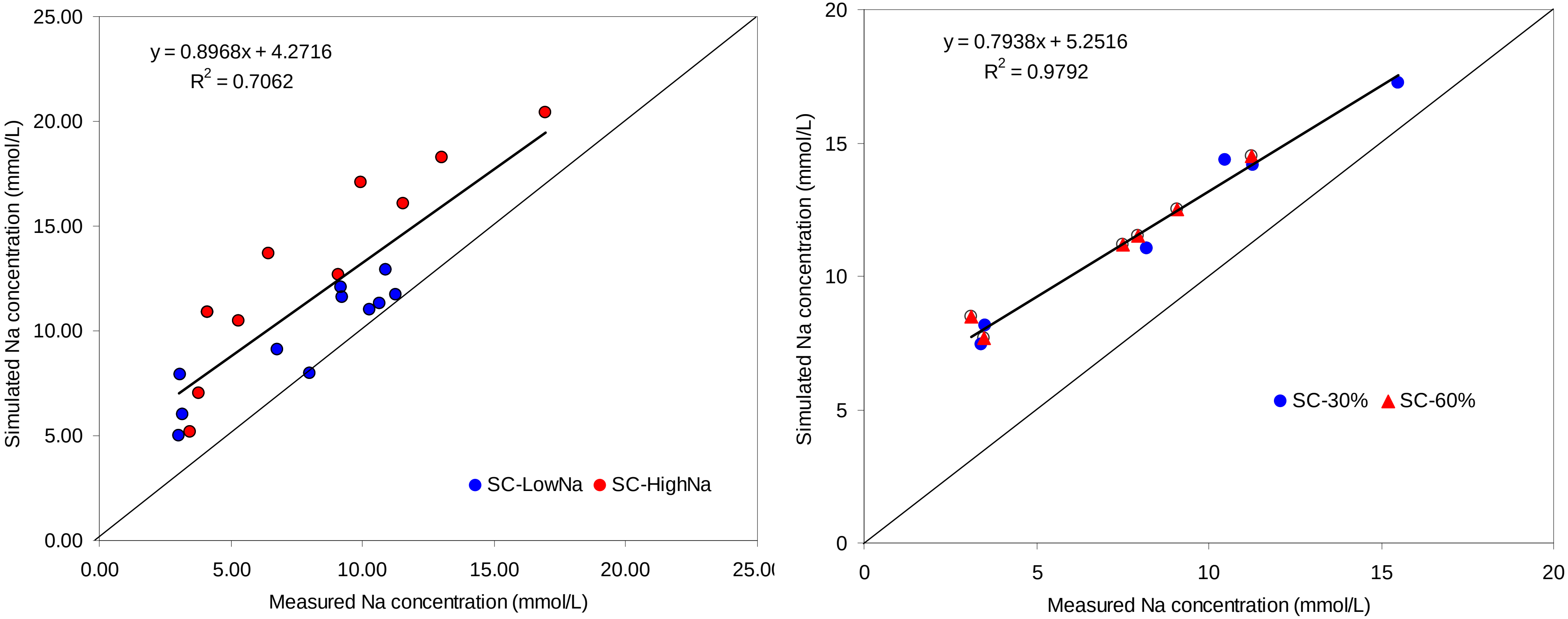




Period 2, February 2012 – July 2012:

1- **open** system, **drainage rate 30%.**
2- **semi-closed** system, **drainage rate 30%,** [Na+] < 15 mmol/L
3- **semi-closed** system, **drainage rate 60%,** [Na+] < 15 mmol/L

Measured vs Modeled Na^+



Kittas et al., 2013. Key on-farm irrigation techniques to save water. Sustainable use of irrigation water in the Mediterranean Region (Sirrimed). Project report. WP1.

Measured vs Modeled Na^+

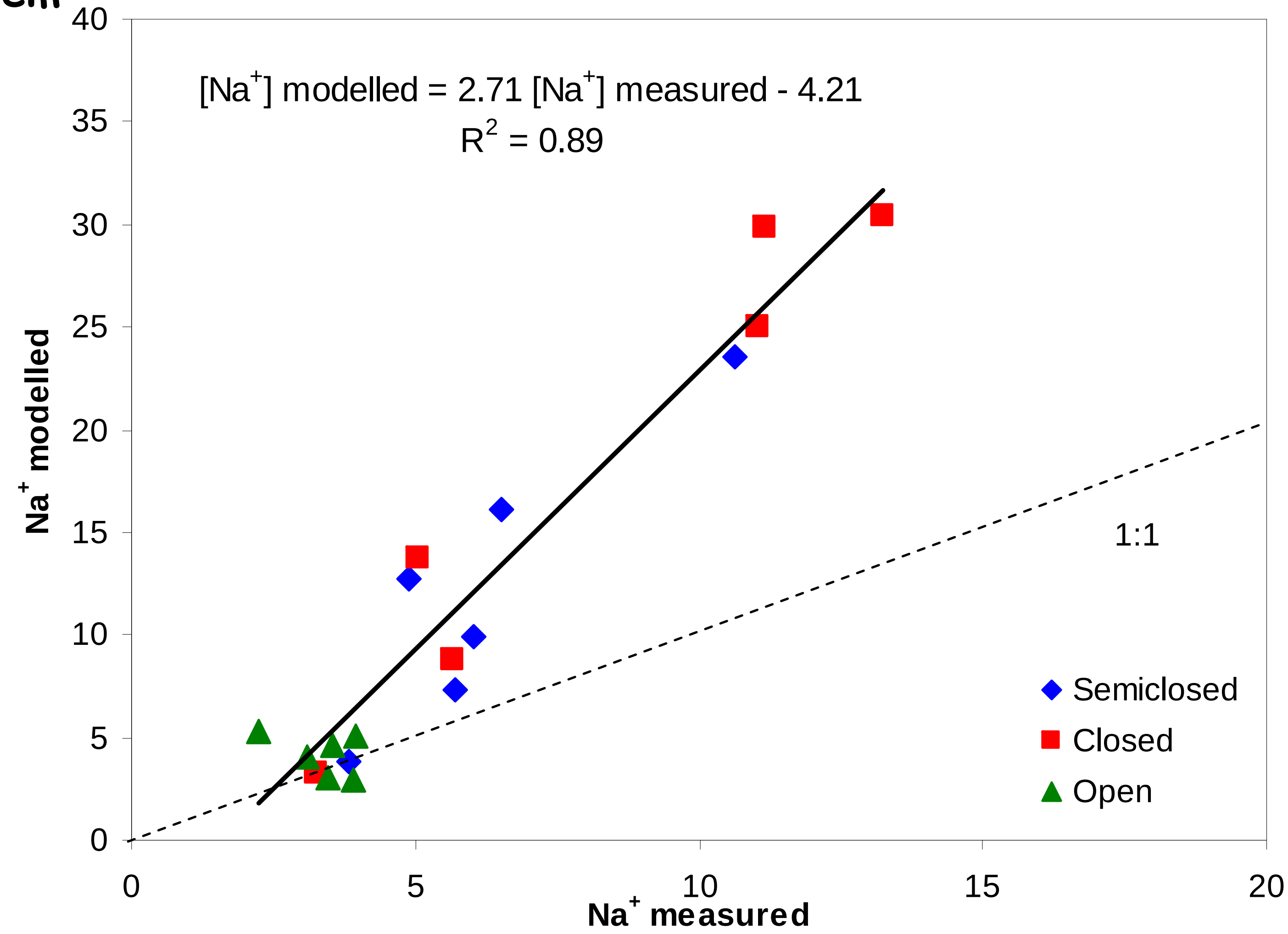
Period 3, December 2010 – July 2011:

1- **open system**.

2- **closed system**.

3- **semi-closed system**

Tomato variety different than the one used during model calibration by Varlagas et al. (2010)



DSS for on-line control of [Na^+]

The DSS performance evaluation results indicate that the system developed could control Na^+ concentration in the hydroponic system but correction of the model may be needed for the type of cultivar used.

Kittas et al., 2013. Key on-farm irrigation techniques to save water. Sustainable use of irrigation water in the Mediterranean Region (Sirrimed). Project report. WP1.

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4. Future Perspectives

Future perspectives

- Development of salt-tolerant cultivars by screening, conventional breeding, and genetic engineering? Grafting?
- Selective ion removal (specific membranes, capacitive de-ionisation)?
- Better management of nutrient solution – use of ion selective sensors?