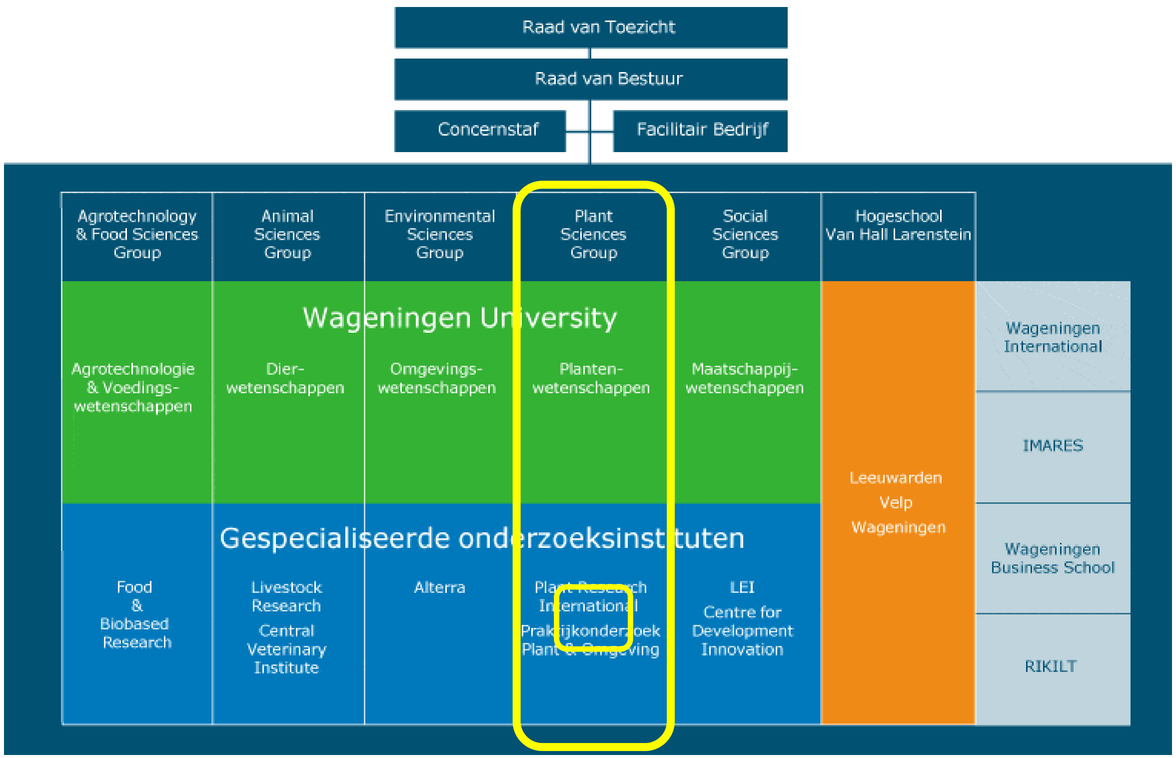
Effect of N concentrations and N-form on yield and fruit quality of soil-less grown fruit-vegetables.

Wim Voogt

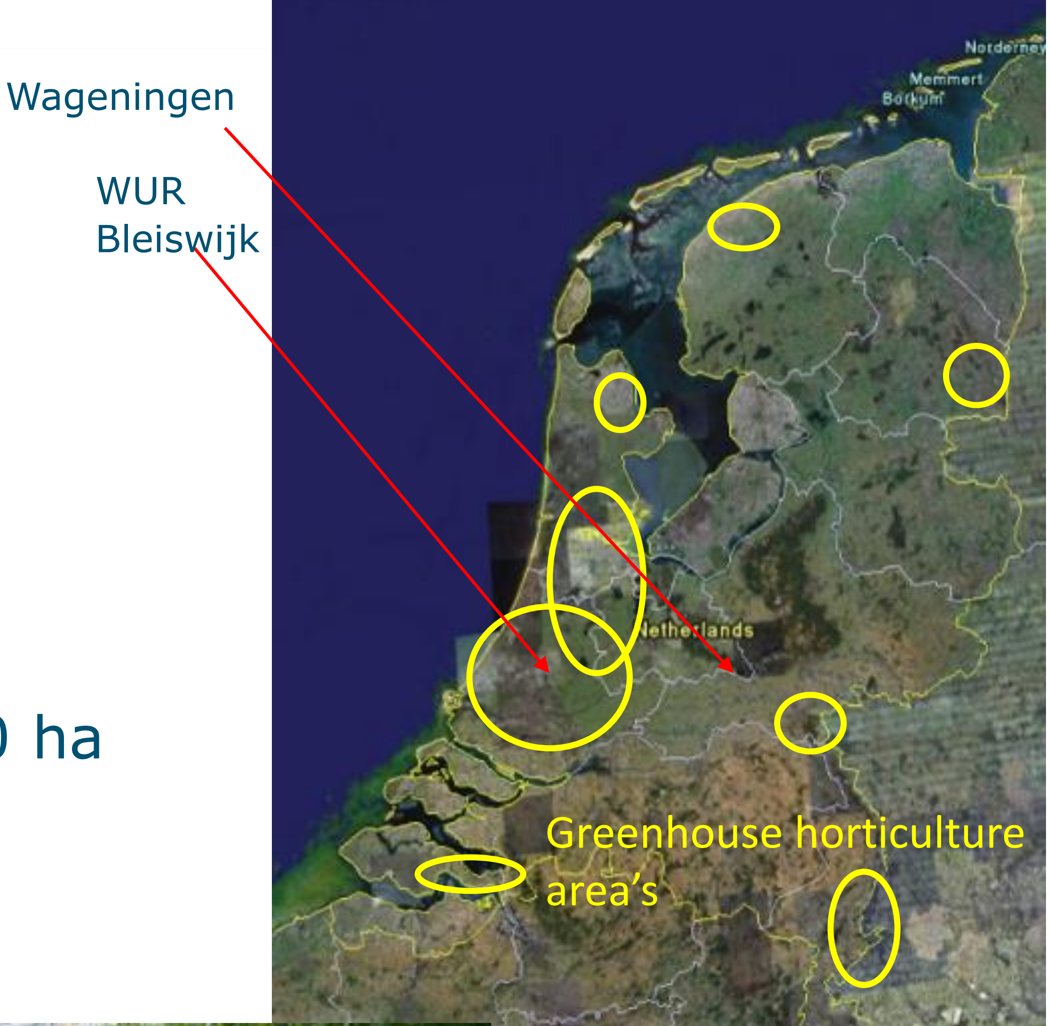
Wageningen University and Research
Greenhouse Horticulture
Bleiswijk, NL

WAGENINGEN
UNIVERSITY & RESEARCH

Wageningen University and Research



WAGENINGEN
UNIVERSITY & RESEARCH



Greenhouse Horticulture in The Netherlands: 10500 ha

85 % soilless culture

1500 ha tomato

1000 sweet pepper

500 cucumber

250 strawberry

WAGENINGEN
UNIVERSITY & RESEARCH

Content

- Nitrogen in soilless culture
  - N-availability
  - N quantity - concentration
  - N sources
- Effect of N on yield and fruit quality
  - N-concentration
  - N-sources
- Evaluation, practical implications

Differences between soil and soil-less

Soil

- Big volume : 300 – 600 l/m2
- Large buffer: water /nutrients
- Nutrient Exchange capacity
- Large pH buffer
- Organic matter / soil micro organisms (*mineralisation, immobilisation, denitrification*
- Fertilisation taking into account the soil properties

Soil-less

- Small volume 10 l/m2
- water, nutrient buffer almost non existent
- No nutrient exchange capacities
- Inert media
- No pH buffer
- No organic matter interactions
- Fertilisation based on crop requirements, water uptake

Fertiliser application

Quantity of available N in greenhouse crops

	Soil light clay 60 cm rooting depth	Substrate rockwool 20 cm slab, V-system	Hydroponic NFT 30 cm gutter
substrate volume l/m2	300	9.3	2
Crop demand N kg N/ha (60 kg/m2)	1350	1350	1350
Concentration mg/l (soil solution)	168	308	308
Available kg/ha	504	29	6
% of total demand	37%	2.1%	0.5%

Fertigation in soil -less systems

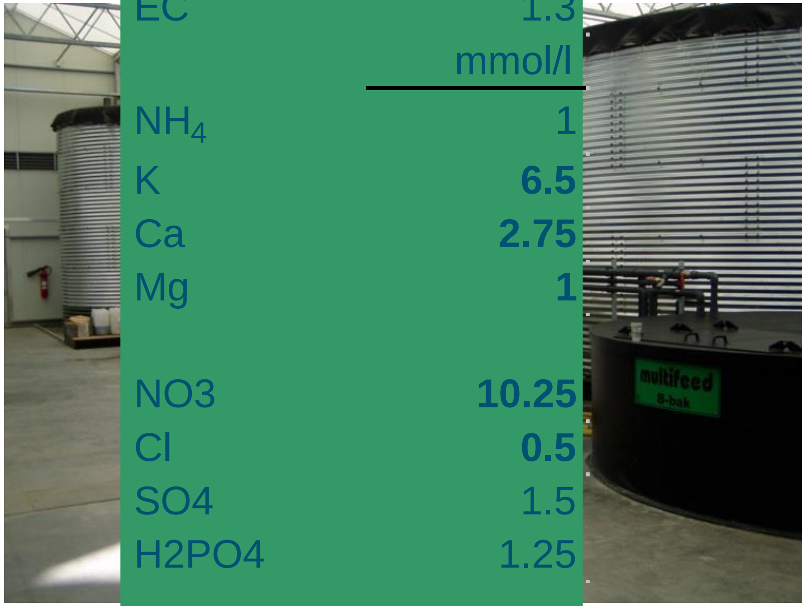
1. Concentrations instead of quantities

- fertigation / soil solution
- EC control
- Nutrients mg/l or mmol/l

2. Nutrient ratio’s

- K : Ca , N : K , Ca : Mg

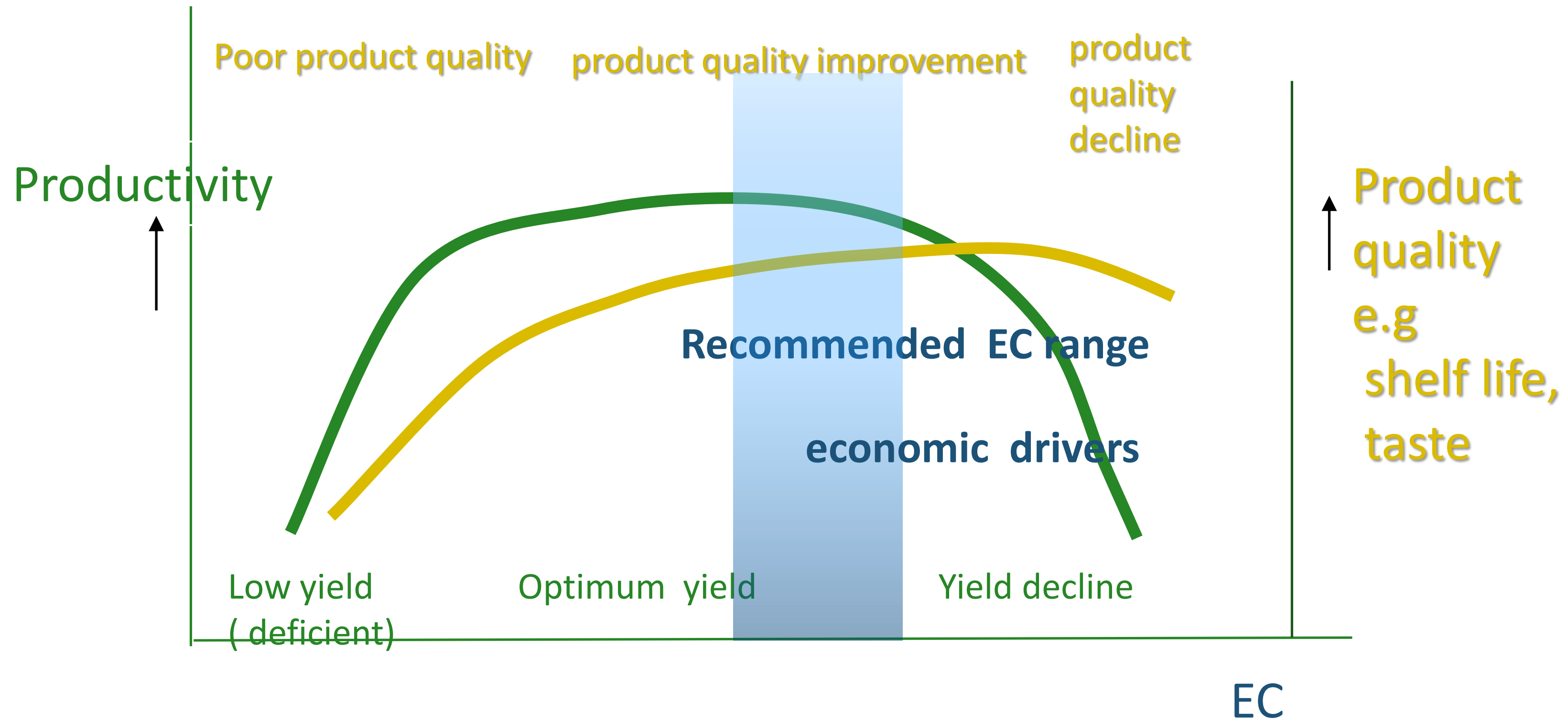
- **Nutrient solutions**



EC	1.3
	mmol/l
NH_4	1
K	**6.5**
Ca	**2.75**
Mg	**1**
NO3	**10.25**
Cl	**0.5**
SO4	1.5
H2PO4	1.25
Si	0
	umol/l
Fe	**15**
Mn	**10**
Zn	4
B	**20**
Cu	**0.75**
Mo	**0.5**

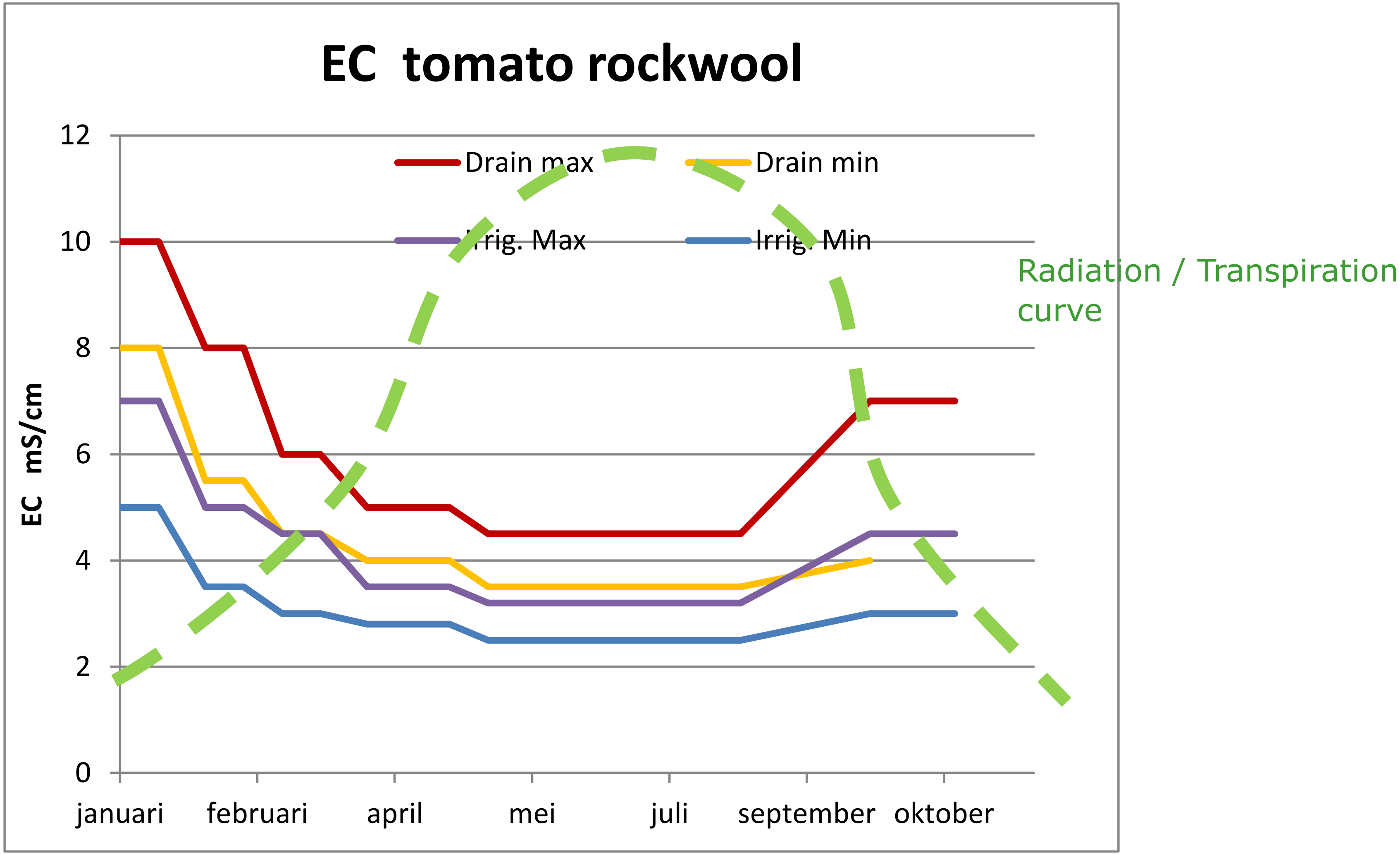
WAGENINGEN
UNIVERSITY & RESEARCH

Effect of EC on crops



WAGENINGEN UNIVERSITY & RESEARCH

Recommended EC during season



WAGENINGEN
UNIVERSITY & RESEARCH

Difference between required EC and nutrients

Tomato **Open system,** **(free drainage)**	total Ion sum													
	EC	cations	anions	NH4	Na	K	Ca	Mg	NO3	Cl	SO4	H2PO4	N-total	
	dS.m-1	me/l		mmol.l-1									mmol/	mg/l
Standard														
supply	2.6	26	26	1.2		9.5	5.4	2.4	15.8		4.5	1.5	17.0	238
Target Root env.	3.7	37	37	0.1		8.0	10.0	4.5	24.0		6.0	1.0	24.1	337

WAGENINGEN
UNIVERSITY & RESEARCH

Difference between required EC and nutrients

Tomato Open system, (free drainage)	total Ion sum													
	EC	cations	anions	NH4	Na	K	Ca	Mg	NO3	Cl	SO4	H2PO4	N-total	
	dS.m-1	me/l		mmol.l-1									mmol/l	mg/l
Standard														
supply	2.6	26	26	1.2		9.5	5.4	2.4	15.8		4.5	1.5	17.0	238
Target Root env.	3.7	37	37	0.1		8.0	10.0	4.5	24.0		6.0	1.0	24.1	337
minimum required														
supply	1.45	15	15	0.5		6.5	2.3	1.5	11.0		1.4	0.8	11.5	161
Target Root env.		20	9	0.0		2.0	6.0	3.0	4.0		2.0	0.5	4.0	56

WAGENINGEN
UNIVERSITY & RESEARCH

Difference between required EC and nutrients

Tomato Open system, (free drainage)	total Ion sum													
	EC	cations	anions	NH4	Na	K	Ca	Mg	NO3	Cl	SO4	H2PO4	N-total	
	dS.m-1	me/l		mmol.l-1									mmol/	mg/l
Standard														
supply	2.6	26	26	1.2		9.5	5.4	2.4	15.8		4.5	1.5	17.0	238
Target Root env.	3.7	37	37	0.1		8.0	10.0	4.5	24.0		6.0	1.0	24.1	337
minimum required														
supply	1.45	15	15	0.5		6.5	2.3	1.5	11.0		1.4	0.8	11.5	161
Target Root env.		20	9	0.0		2.0	6.0	3.0	4.0		2.0	0.5	4.0	56
"space" for additional salts														
supply	2.63	26	26	0.5	11.8	6.5	2.3	1.5	11.0	11.8	1.4	0.8	11.5	161
Target Root env.		37	37	0.0	17.0	2.0	6.0	3.0	4.0	28.5	2.0	0.5	4.0	56

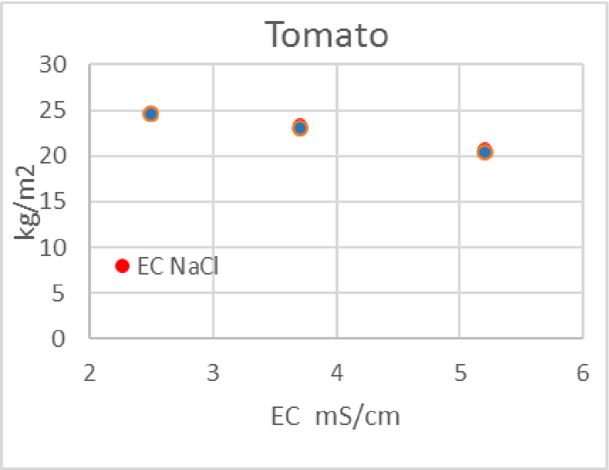
Theoretically 1 – 1.1 dS/m (supply)
Or 2.8 - 2.9 dS/m (root) space for reduction of N

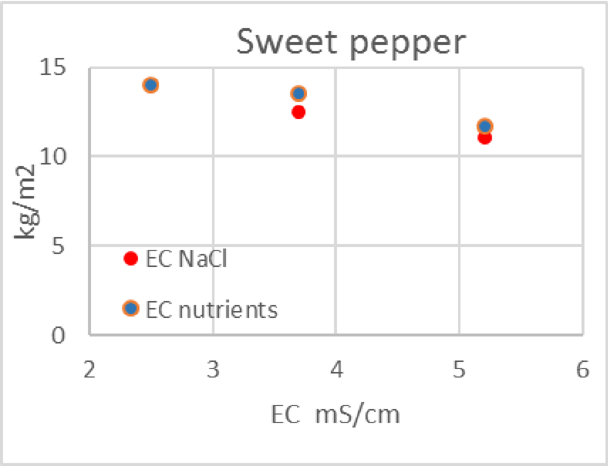
WAGENINGEN
UNIVERSITY & RESEARCH

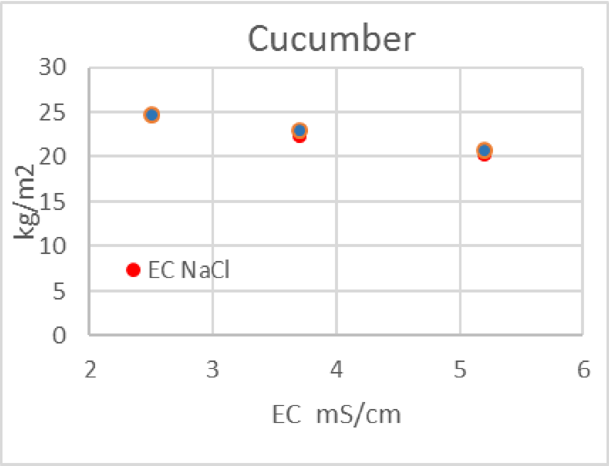
EC or NaCl effect on fruit vegetables

Treatments				
	EC target	EC **Nutrients** mS cm-1	EC **NaCl** mS cm-1	NaCl mmol/l
1	2.5	2.5	0	0
2	3.7	3.7	0	0
3	5.2	5.2	0	0
4	2.5	2.3	0.2	2
5	3.7	2.3	1.4	12.5
6	5.2	2.3	2.9	25

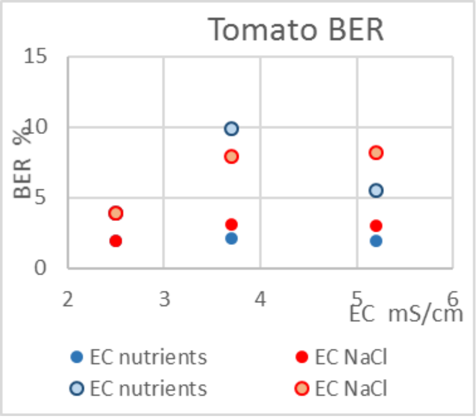
Results   yield

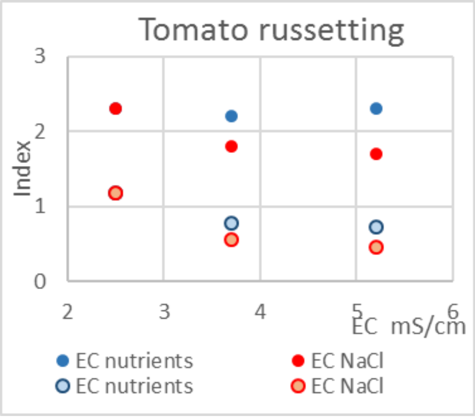


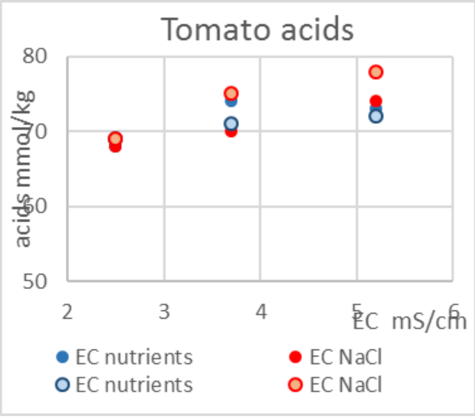


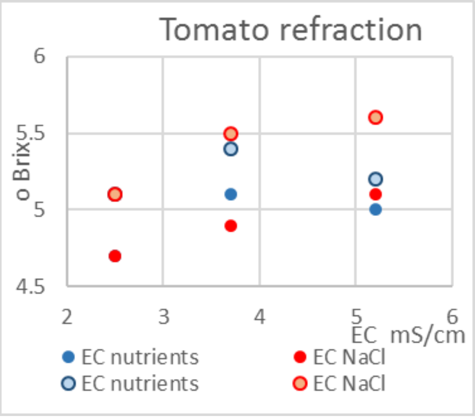


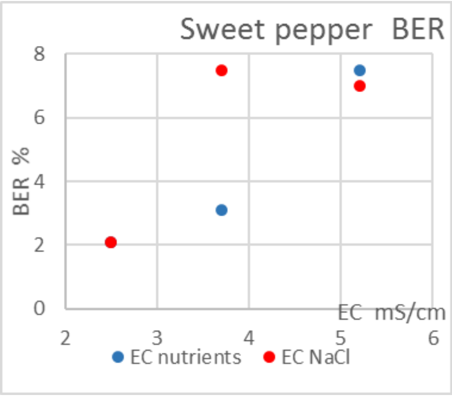
Results quality

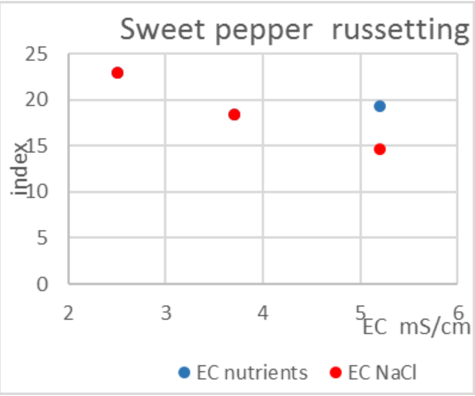


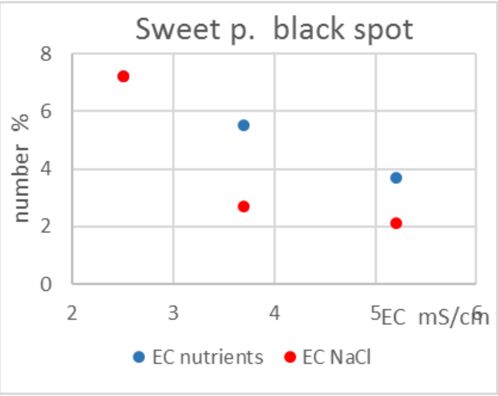


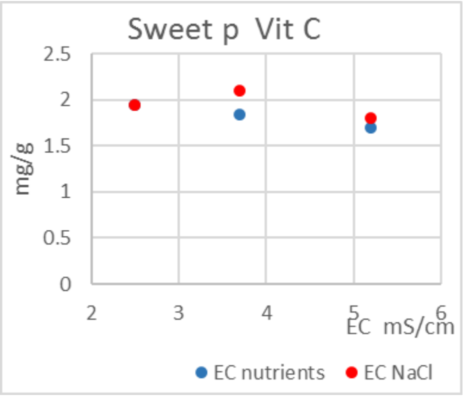












Experiments with N concentration

N – ratios (anions)

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

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

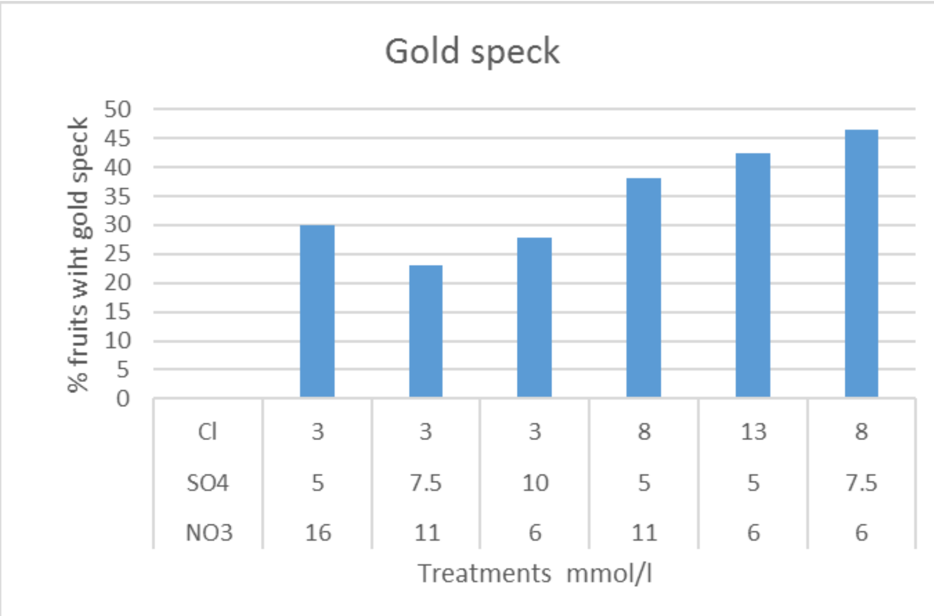
EFFECTS OF NO_3, SO_4 AND Cl RATIOS ON TOMATOES GROWN IN RECIRCULATING SYSTEM

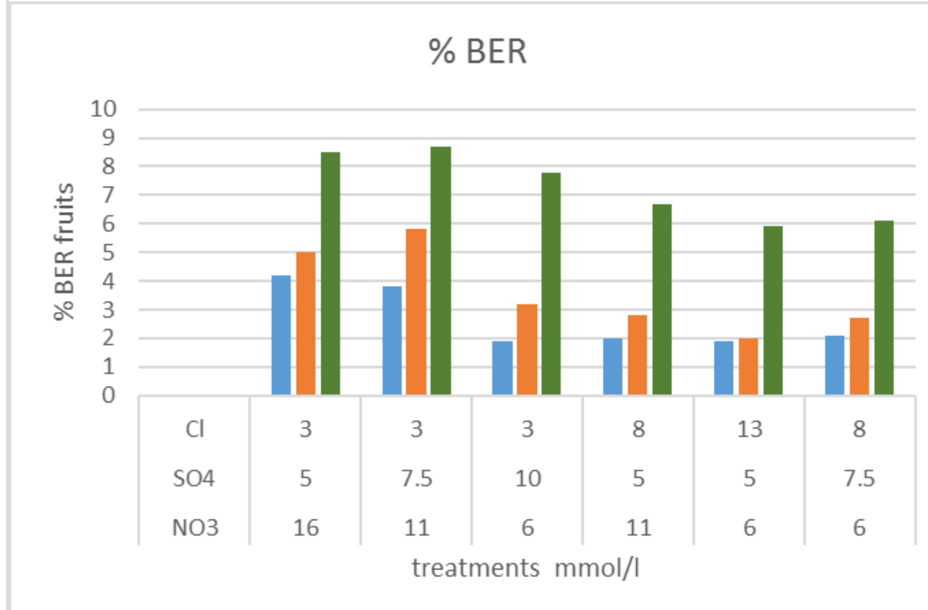
A. Nukaya W. Voogt and C. Sonneveld

Acta Horticulturae 294, 1991
XXIII International Horticultural Congress

WAGENINGEN UNIVERSITY & RESEARCH

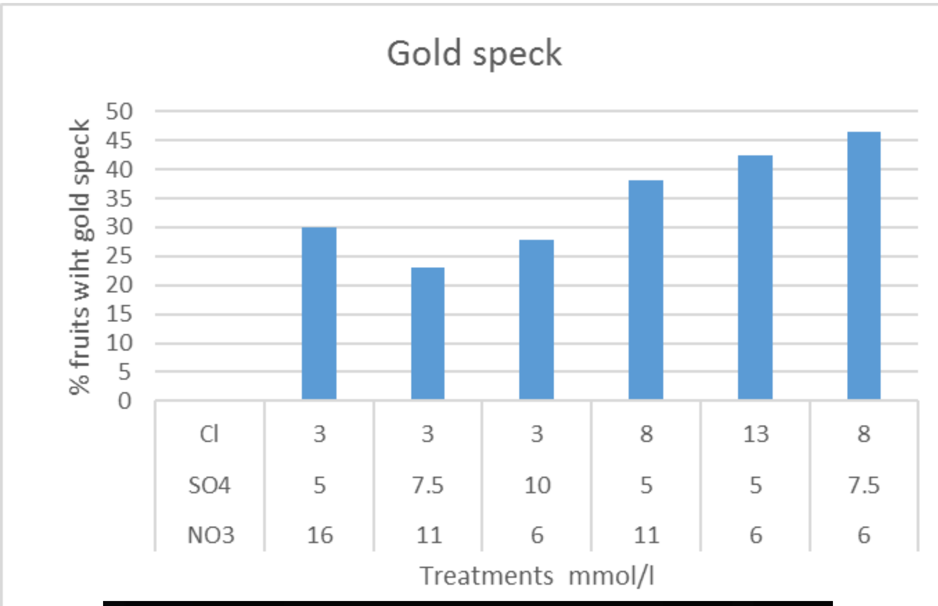
External quality

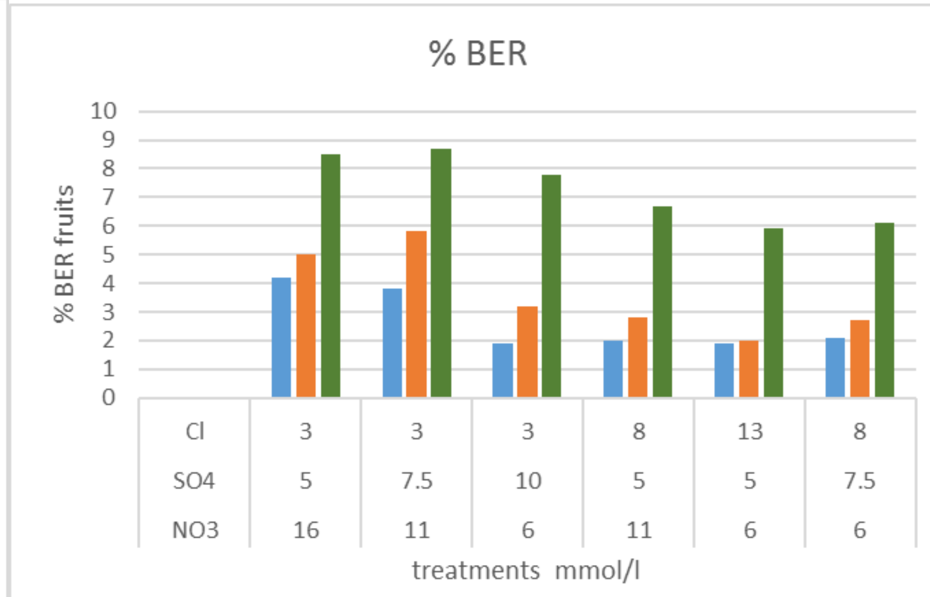


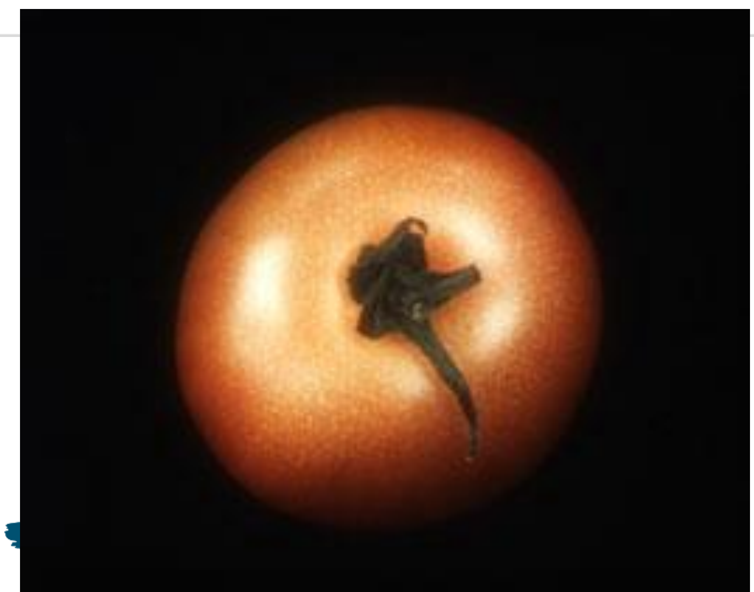


WAGENINGEN
UNIVERSITY & RESEARCH

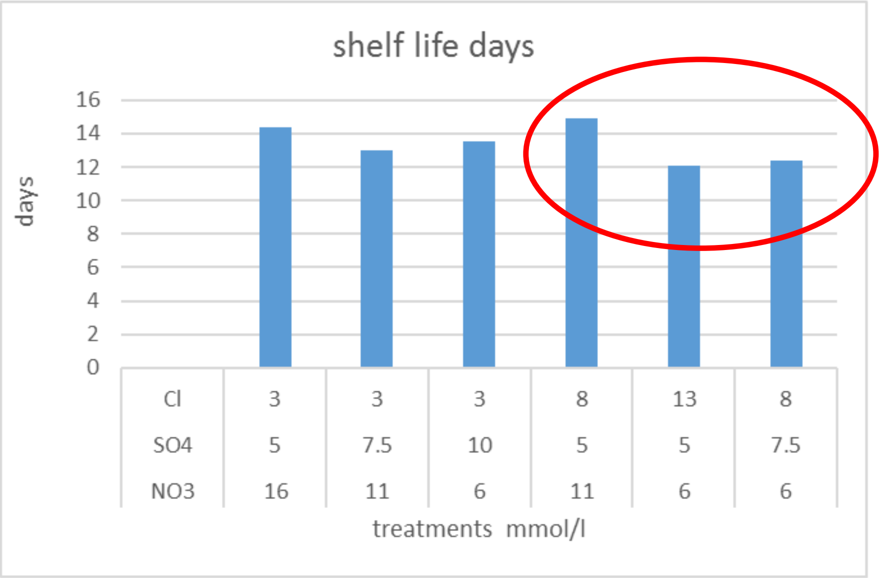
External quality

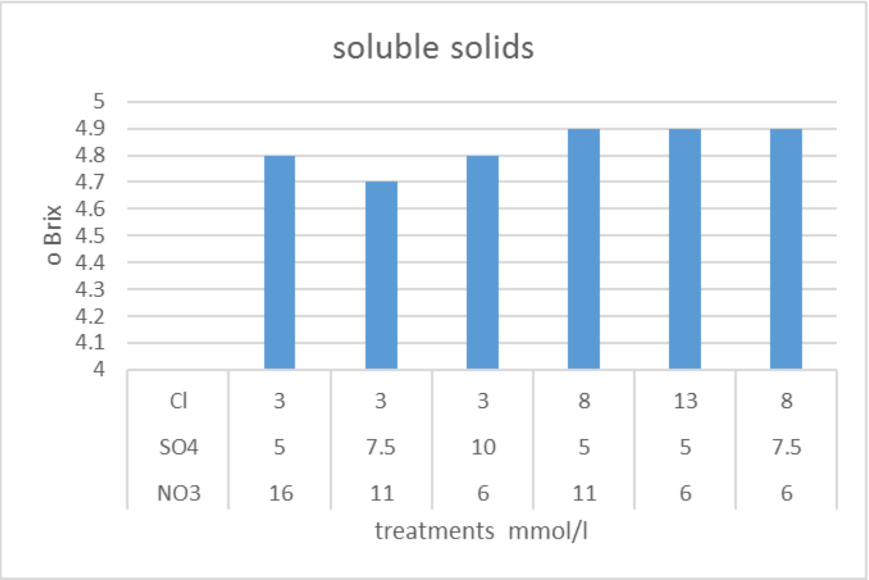


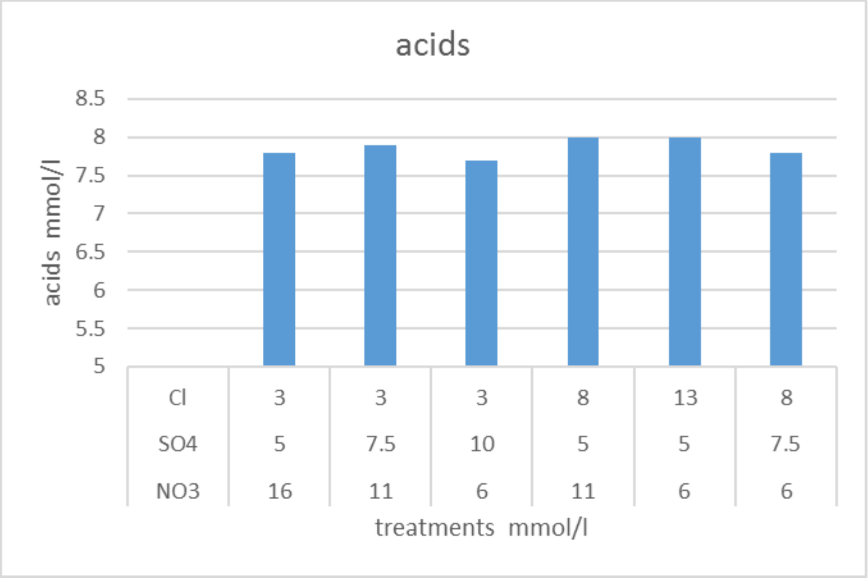




Shelf life and taste parameters







No significant effects

WAGENINGEN UNIVERSITY & RESEARCH

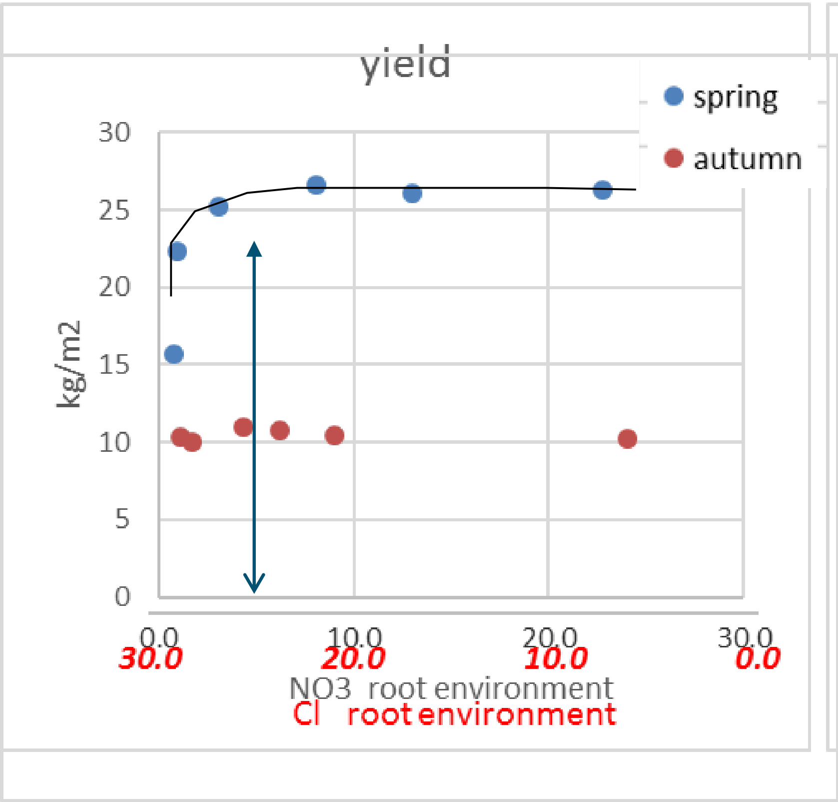
Effect of NO_3 : Cl – ratios; *tomato rockwool closed system*

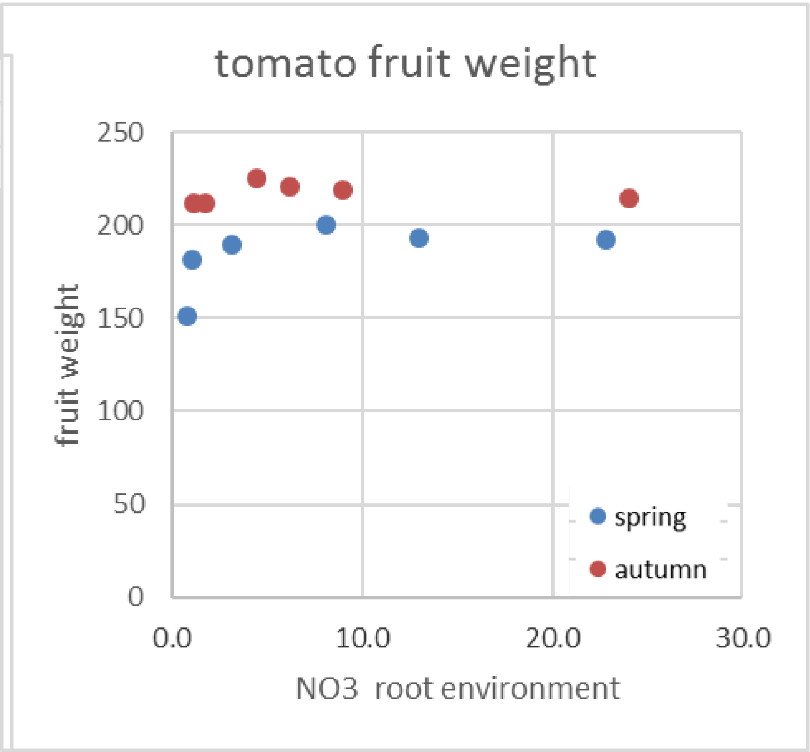
Treatments	Spring crop					Autumn crop		
	EC mS/cm	NO_3 mmol/l	*ppm N*	Cl mmol/l	*ppm Cl*	EC mS/cm	NO_3 mmol/l	Cl mmol/l
1	3.7	22.8	*319*	0.5	*18*	3.7	24	0.5
2	3.7	13	*182*	9.9	*351*	3.8	9	14.1
3	3.7	8.1	*113*	14.3	*508*	3.6	6.2	16.2
4	3.6	3.1	*43*	17.8	*632*	3.6	4.4	16.7
5*	3.7	1	*14*	19.9	*706*	3.7	1.7	18.6
6**	3.8	0.8	*11*	23.6	*838*	3.7	1.1	20.2

Yield

NO_3 supply varied, by replacing with Cl.

Closed recirculation system

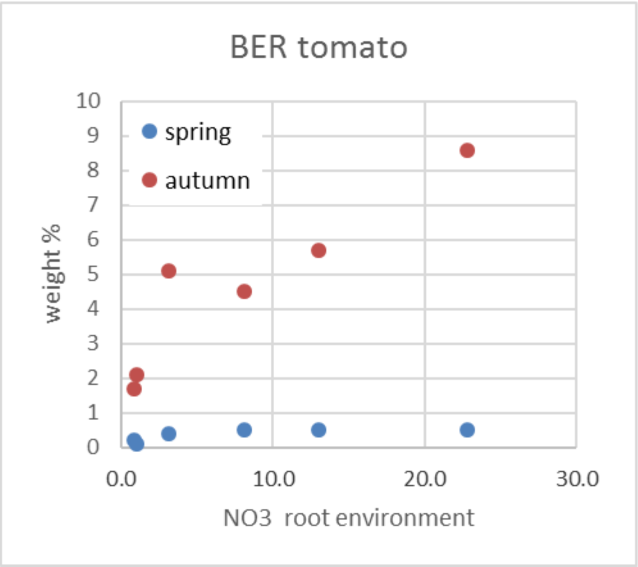


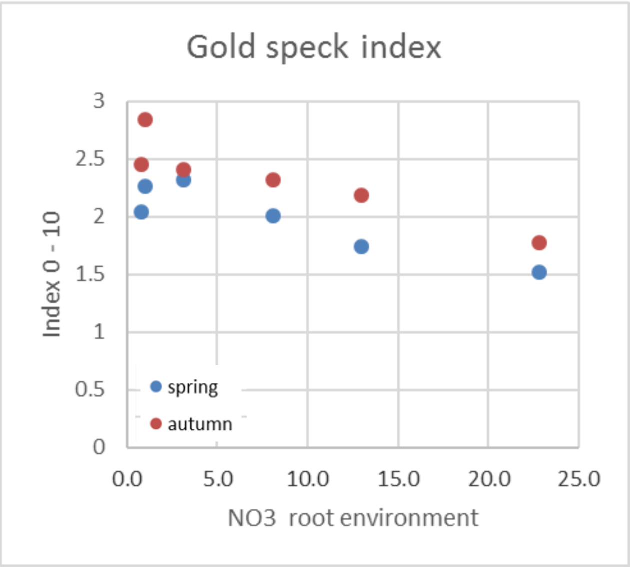


WAGENINGEN UNIVERSITY & RESEARCH

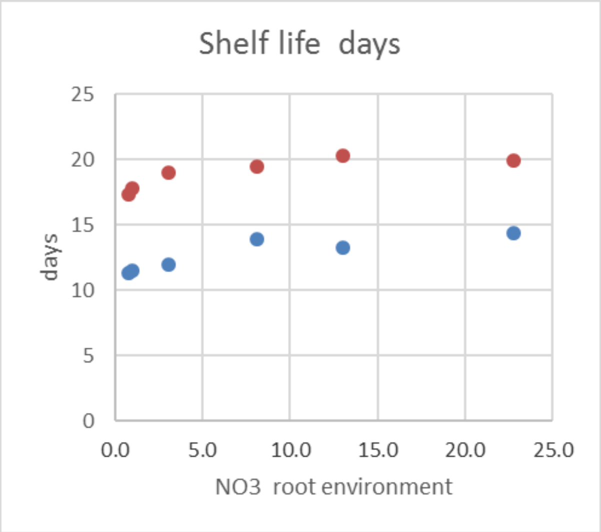
From: Voogt and Sonneveld, 2004. Acta Hort. 644

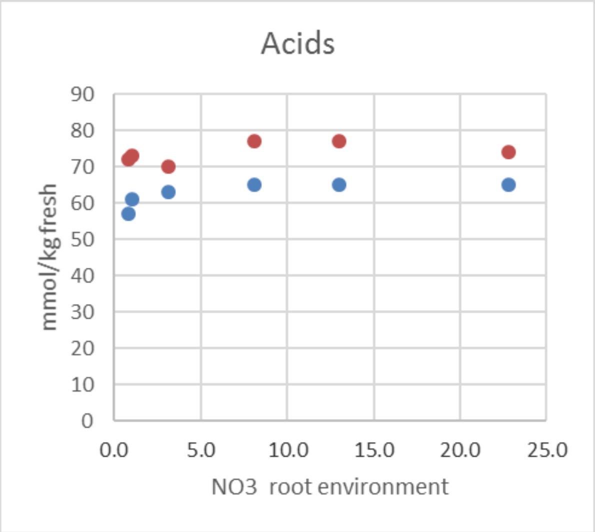
External quality

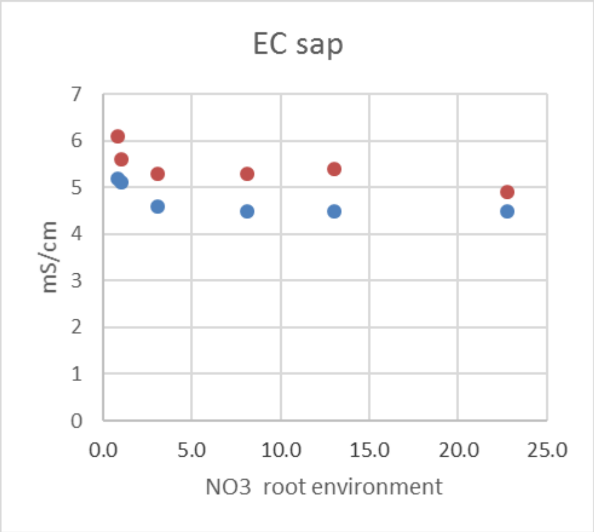


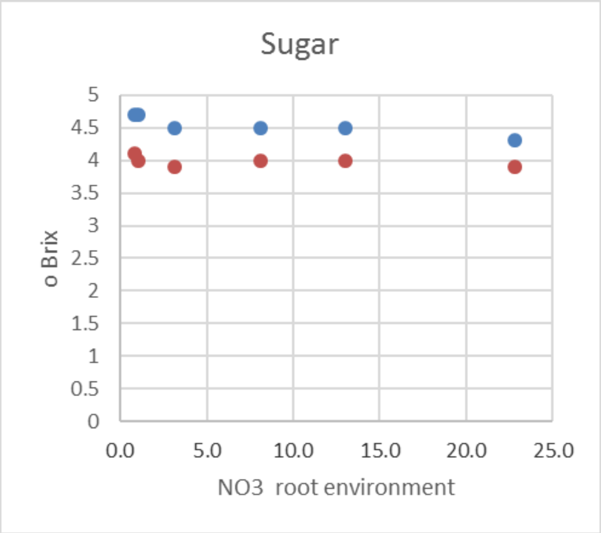


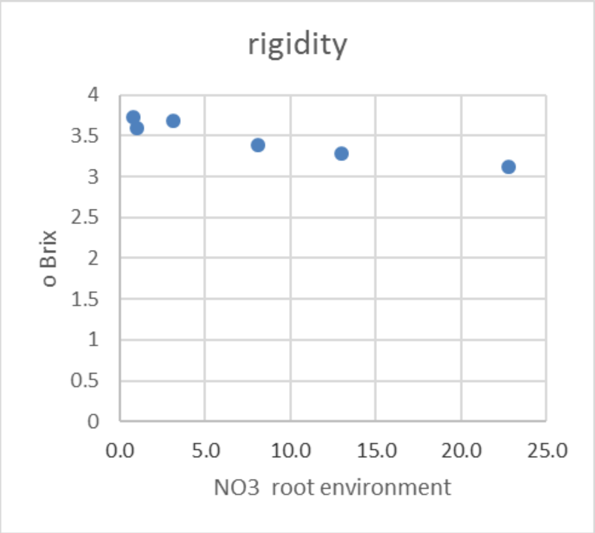
Shelf life - internal quality







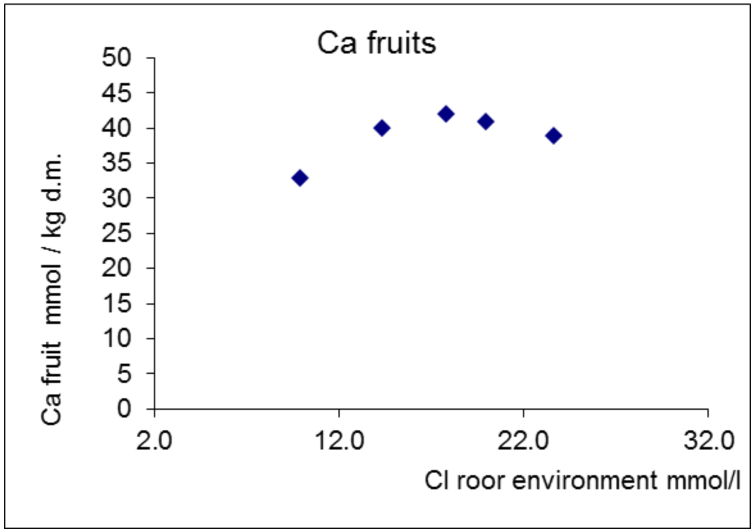


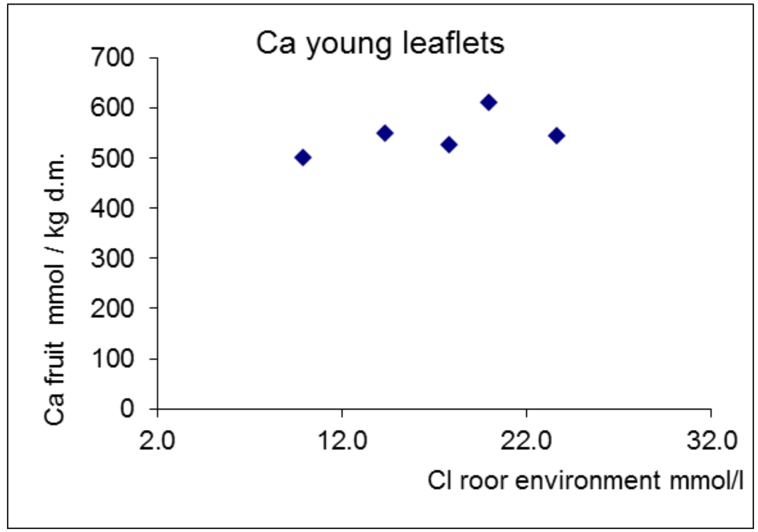


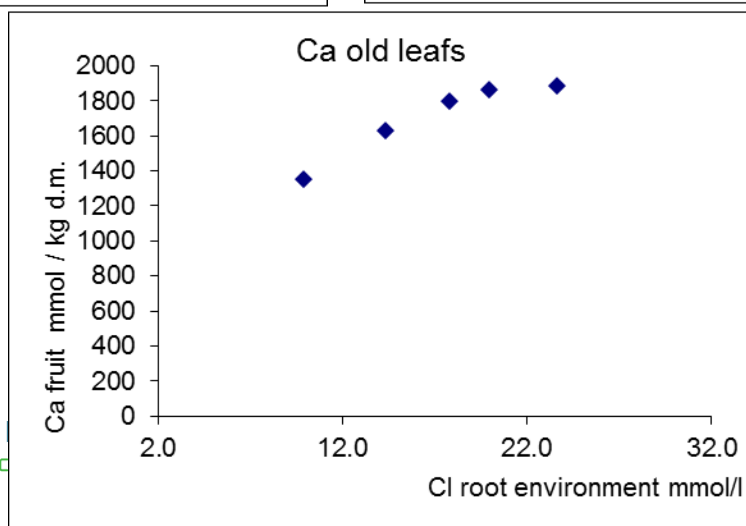
Effect on Ca- uptake

NO_3 supply varied, by replacing with Cl.

Closed recirculation system

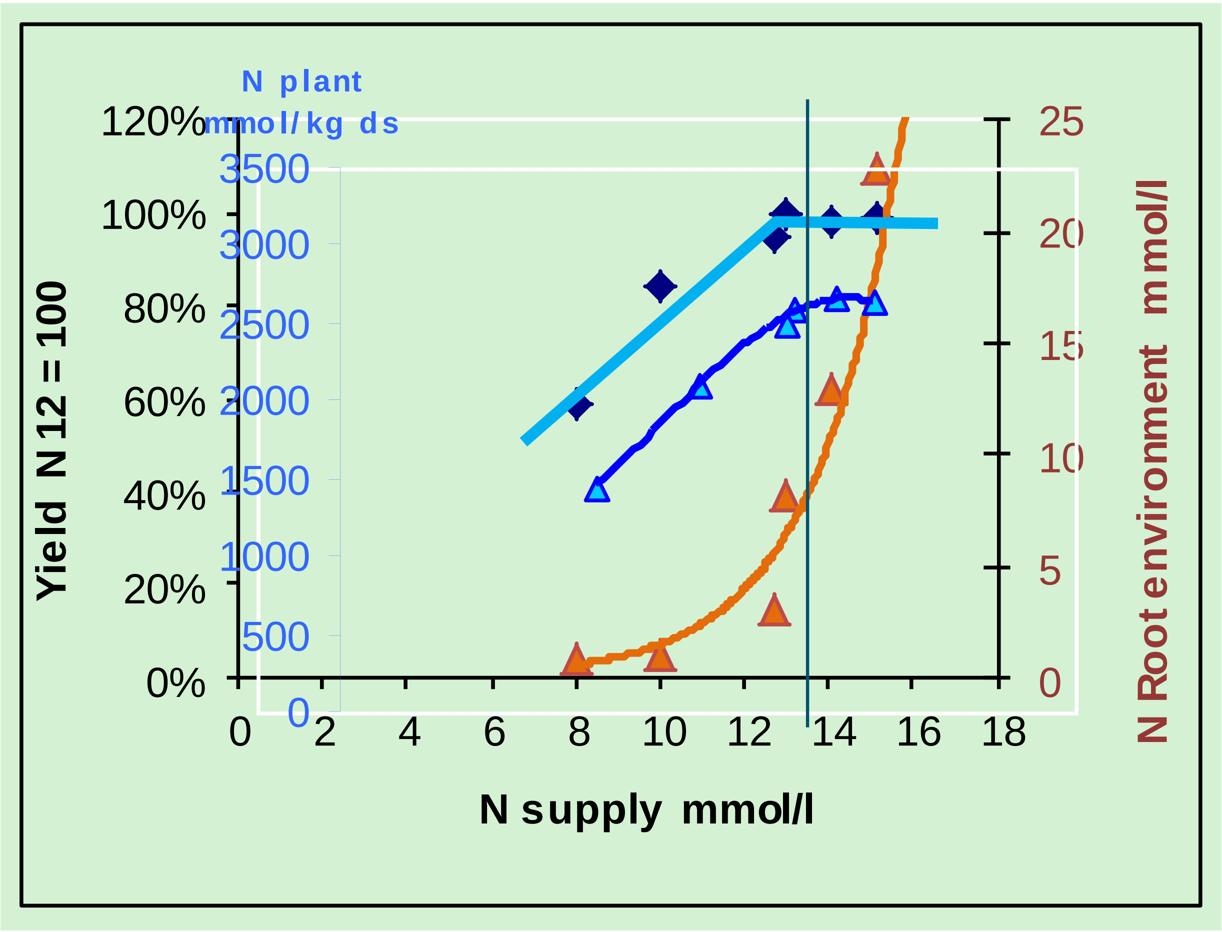






Sonneveld, 2004. Acta Hort. 644

The effect of N supply on tomato yield in closed hydroponic system



WAGENINGEN
UNIVERSITY & RESEARCH

Effect of N form

Nitrogen forms

Uptake

- NO_3^-
- NH_4^+
- Organic form
  - Urea
  - Amino acids

Not explored yet

Practical implications

- NO_3^-
  no practical issues
- NH_4^+
  Rapid uptake
  pH effects
  toxic effect
- Organic (urea, amino-acids)
  - limited uptake,
    need conversion to
    NH4 -> NO3

WAGENINGEN
UNIVERSITY & RESEARCH

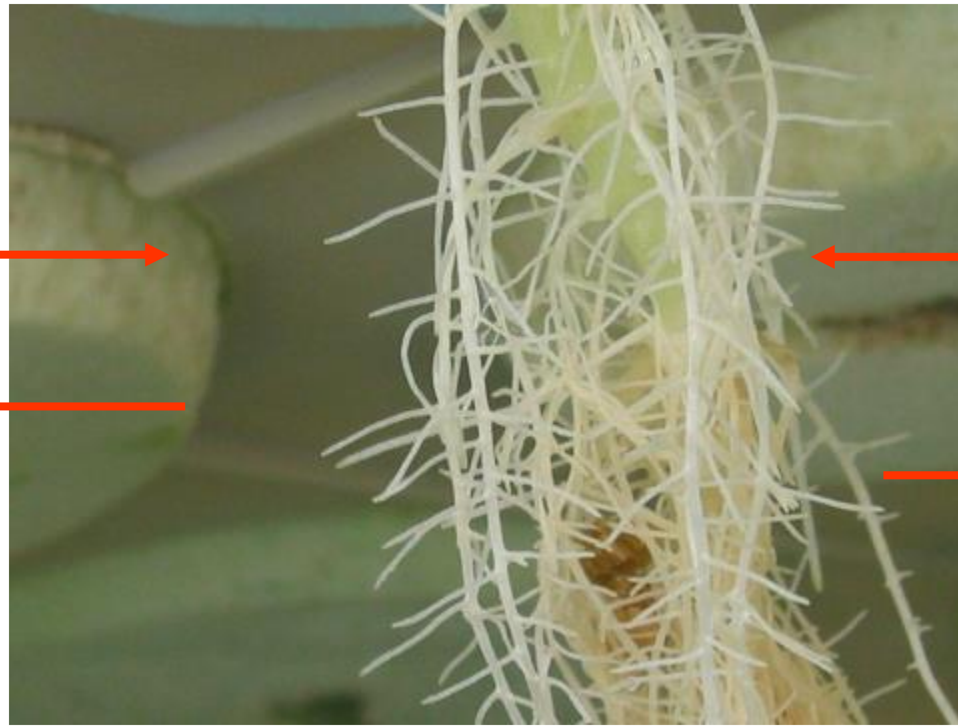
NH_4 and NO_3 uptake effect

NO_3

OH^-

(HCO_3^-)

pH increase



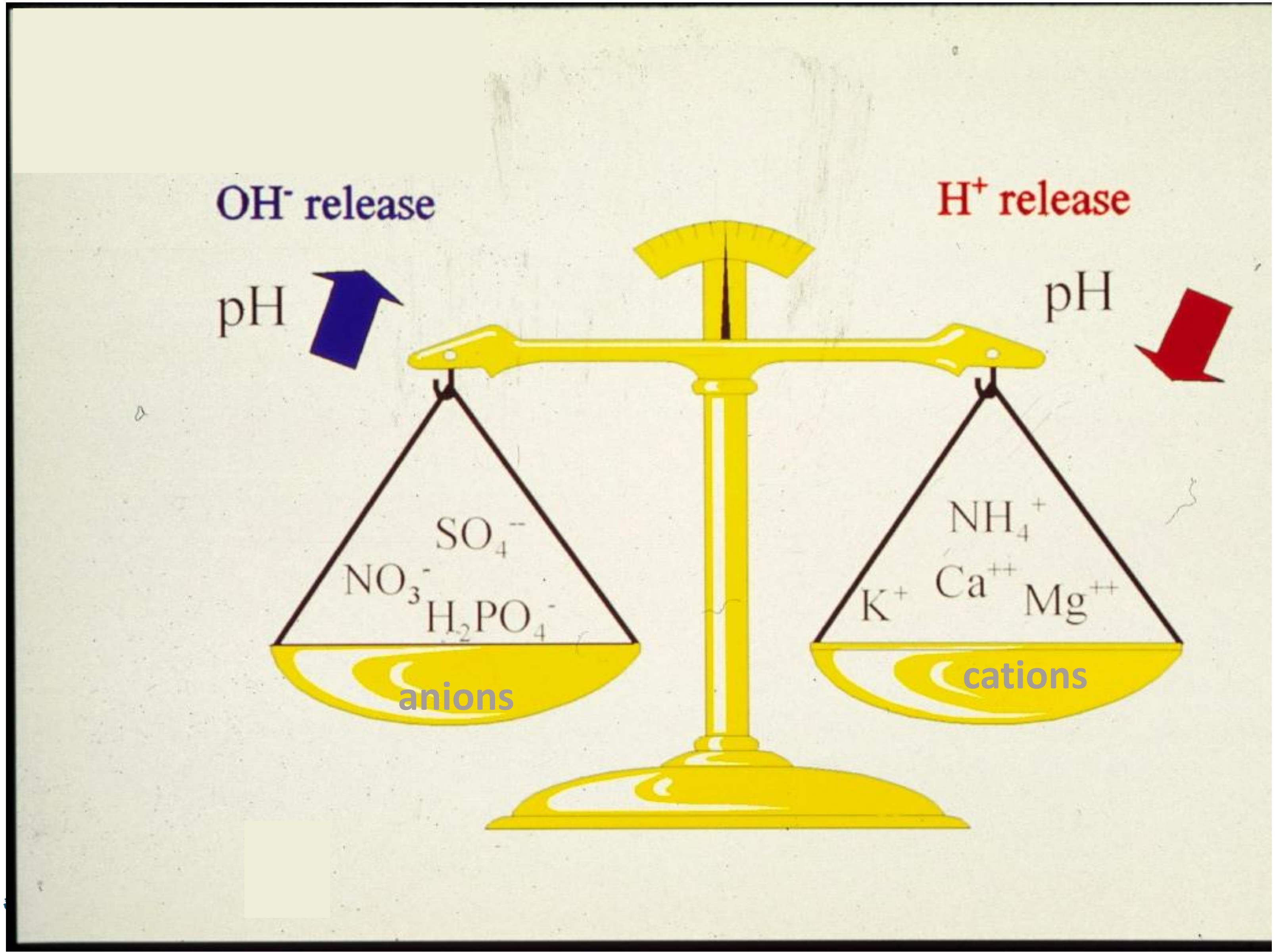
NH_4

H^+

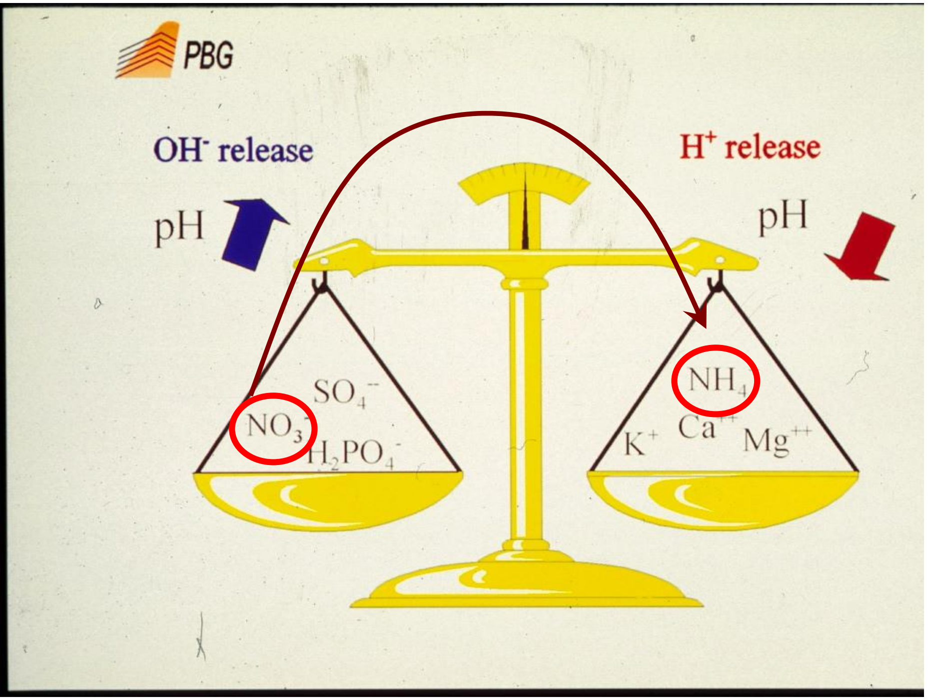
pH decrease

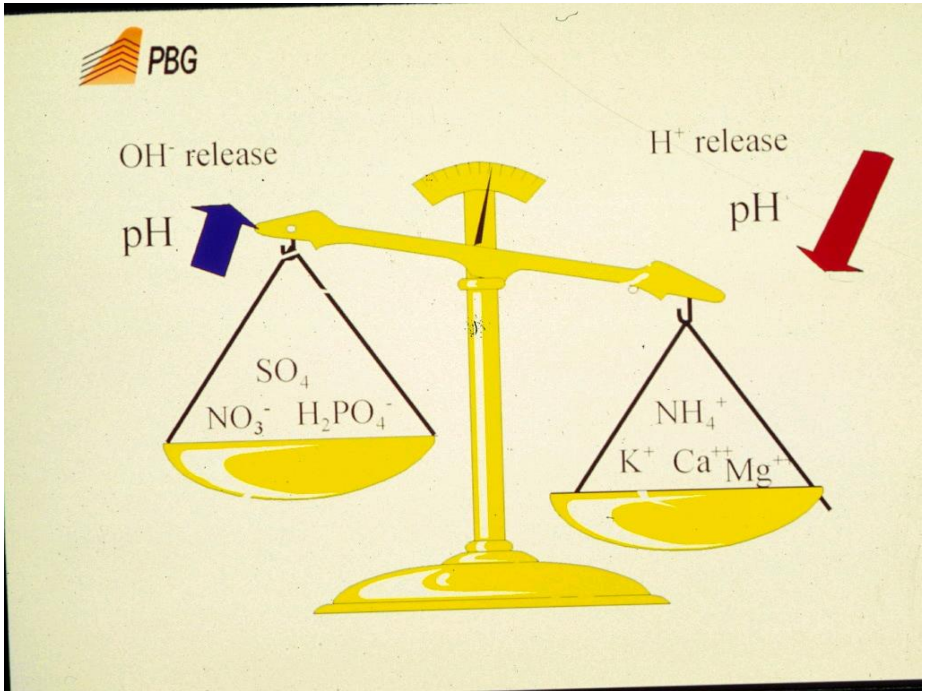
WAGENINGEN
UNIVERSITY & RESEARCH

The cation and anion balance



pH management





WAGENINGEN
UNIVERSITY & RESEARCH

Experiments with N form

Results of N-source trials

- Soil grown crops
- Substrate / hydroponics

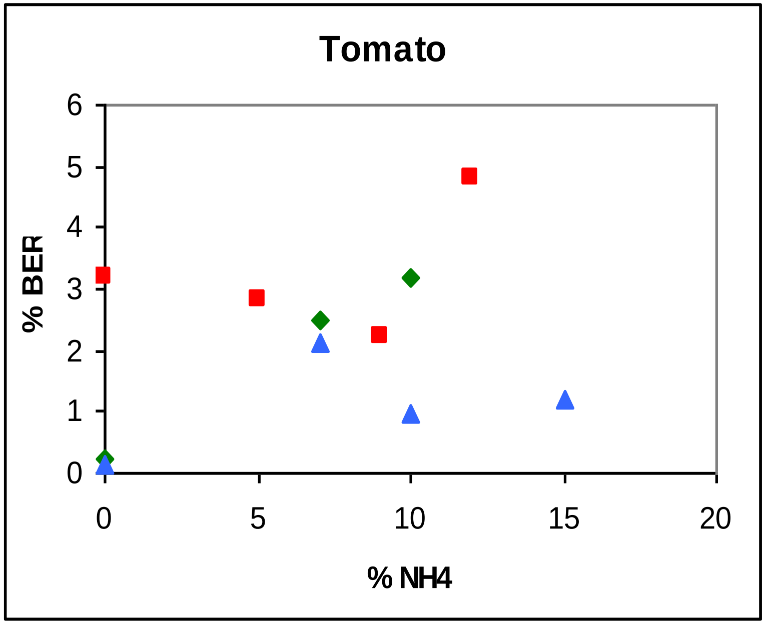
WAGENINGEN
UNIVERSITY & RESEARCH

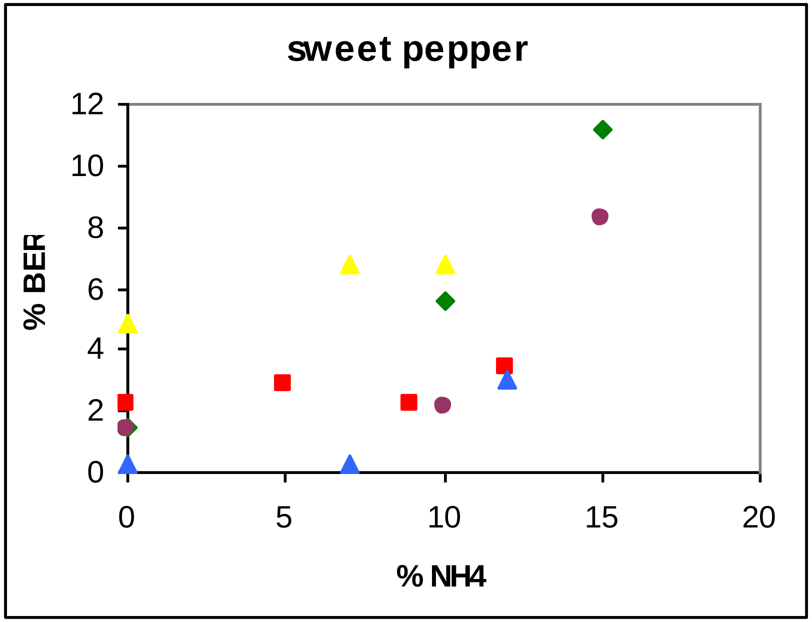
Experimental setup

treatment

NH_4	K	Ca	Mg	NO_3	SO_4	H_2PO_4	NH4-N
0	6.5	2.75	1	11.8	1	1.25	0.0%
0.5				11.3			4.2%
1				10.8			8.5%
1.5				10.3			12.7%
2	5.56	2.36	0.86	9.8	0.87	1.08	16.9%

Blossom End Rot in tomato and pepper





Evolution of pH in the root-environment

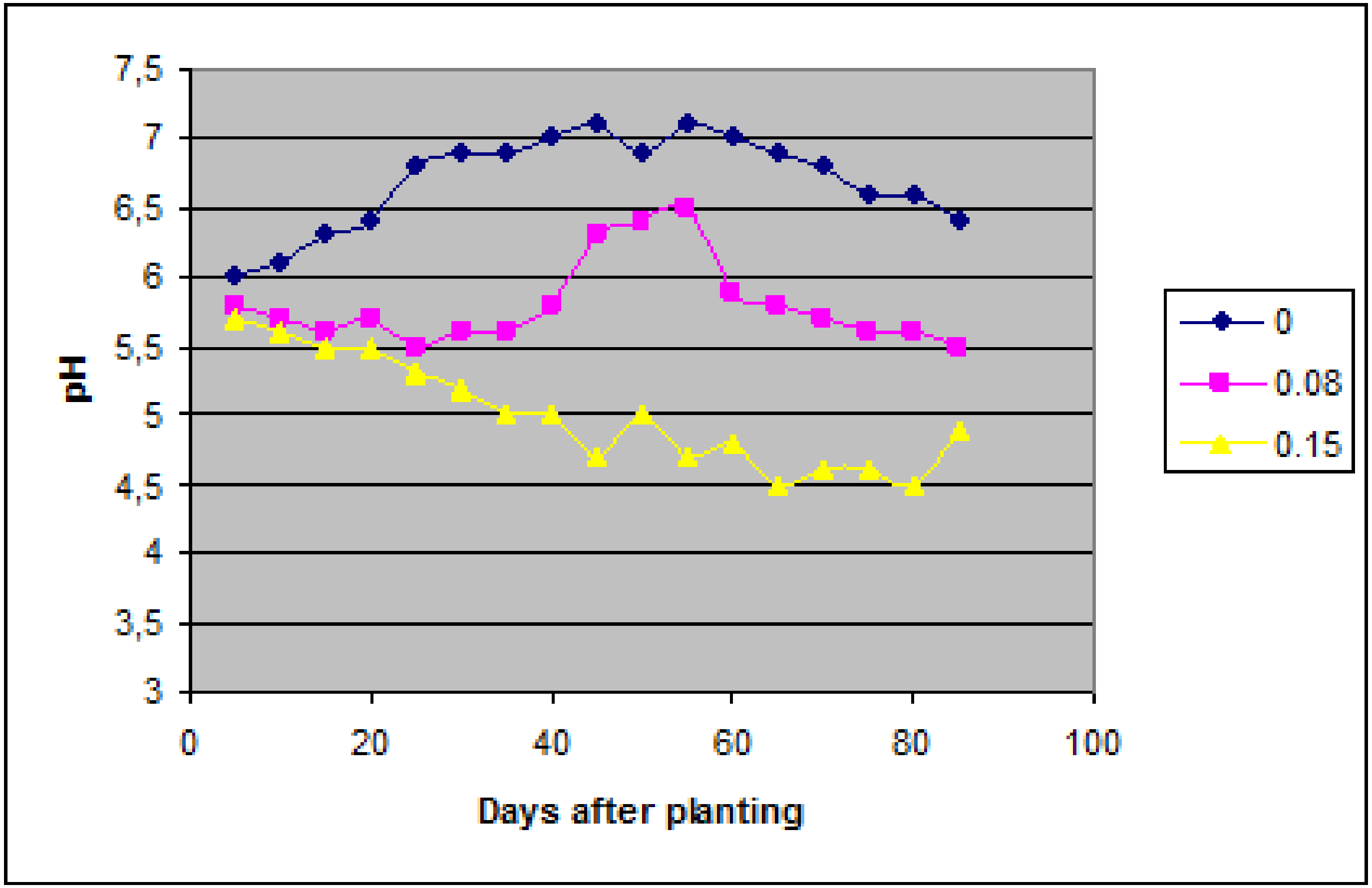


Figure 13.5 Effect of different NH_4/N ratios in the nutrient solution on the pH in the root environment of a rock wool grown cucumber crop. Sonneveld and Voogt , (2009).

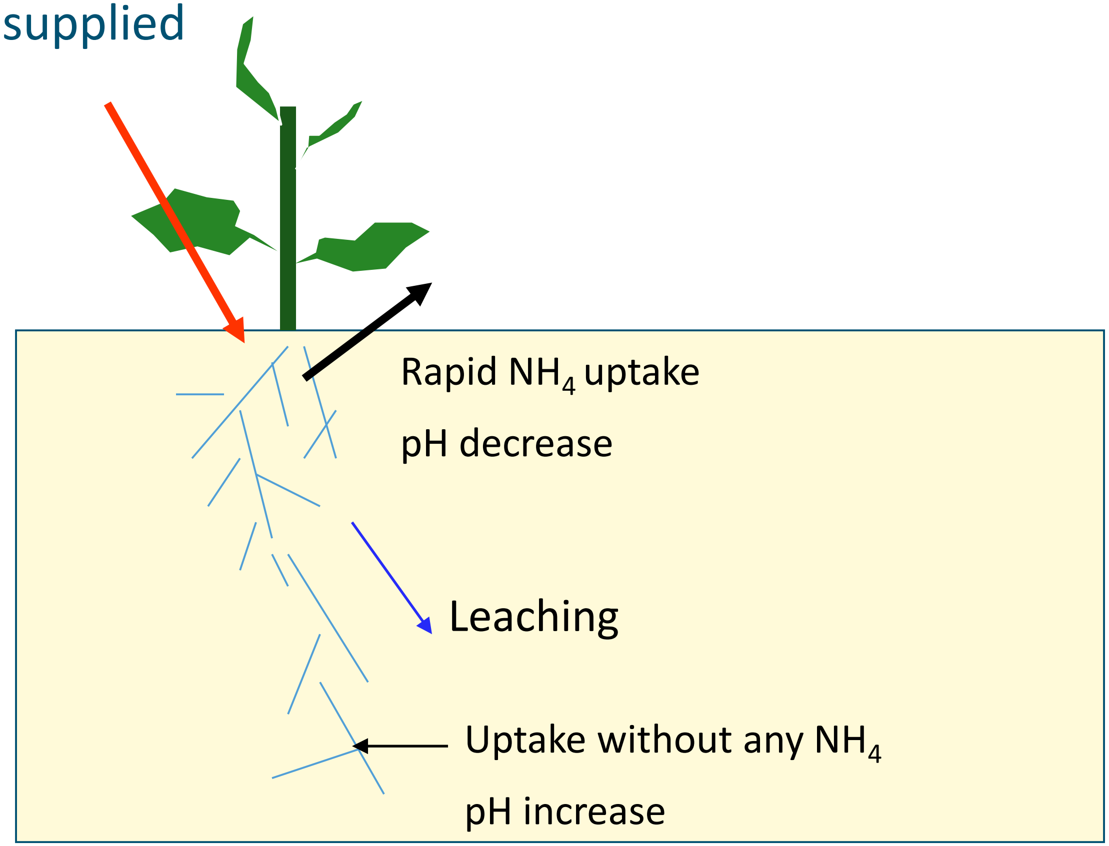
WAGENINGEN UNIVERSITY & RESEARCH

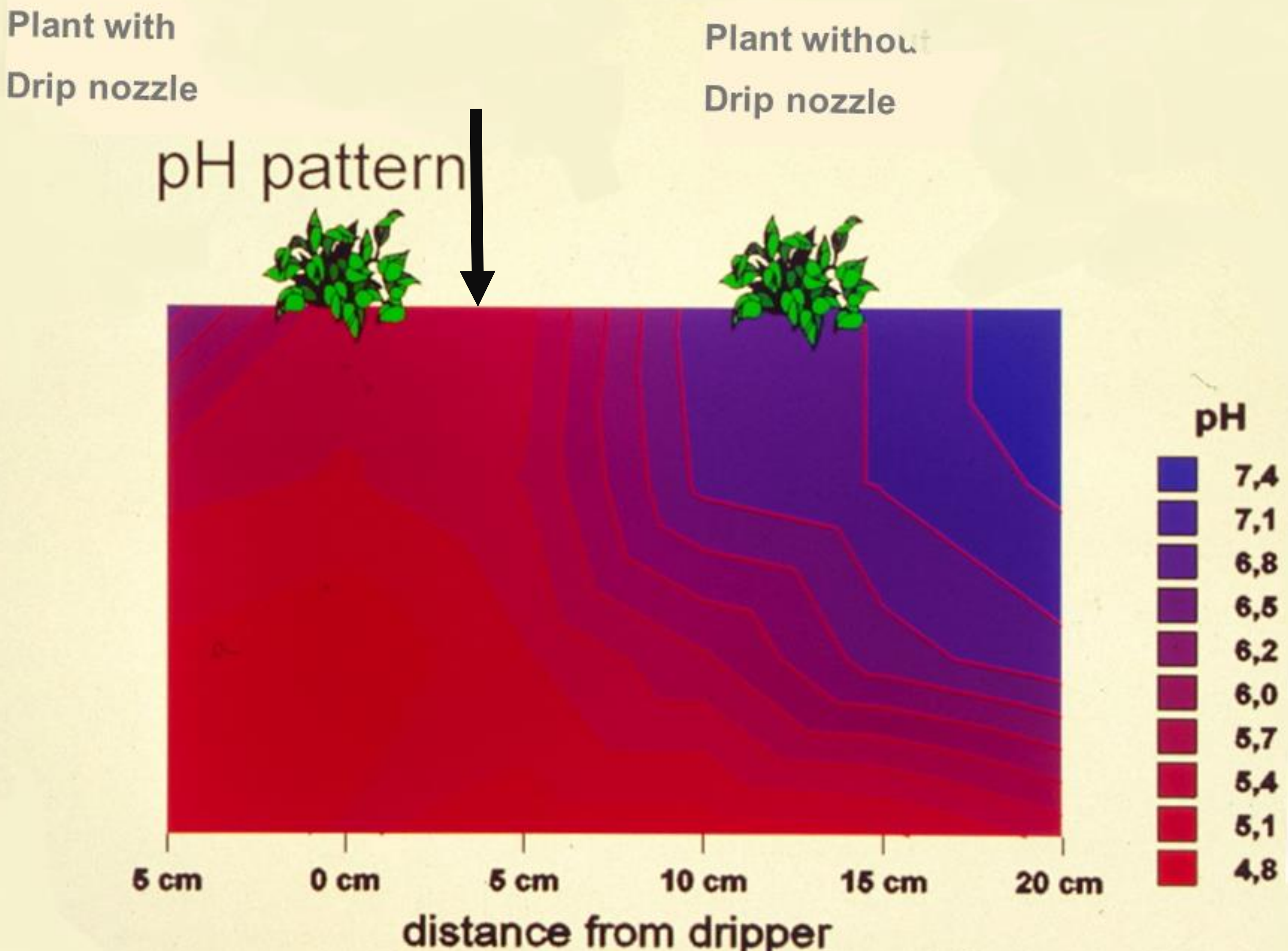
Local pH effect in substrate

Nutrient solution supplied

5 % (NH_4)

Drip irrigation




Plant with
Drip nozzle
Plant without
Drip nozzle
pH pattern
pH
7,4
7,1
6,8
6,5
6,2
6,0
5,7
5,4
5,1
4,8
5 cm
0 cm
5 cm
10 cm
15 cm
20 cm
distance from dripper

Research question:
is it effect of N-form (NH_4) or pH?

WAGENINGEN
UNIVERSITY & RESEARCH

Experimental setup

	pH	treatment NH4	NH4:NO3	% of N
1	4.5 - 5.0	0	0	
2	5.3 - 5.8	0	0	
3	6.2 - 6.5	0	0	
4	4.5 - 5.0	1.5	0.13	11.7%
5	5.3 - 5.8	1.5	0.13	11.7%
6	6.2 - 6.5	1.5	0.13	11.7%
7	4.5 - 5.0	3	0.29	22.8%
8	5.3 - 5.8	3	0.29	22.8%
9	6.2 - 6.5	3	0.29	22.8%

pH = target values in root environment automatic control (HNO_3 KOH)
NH_4 fixed ratio in nutrient solution supplied

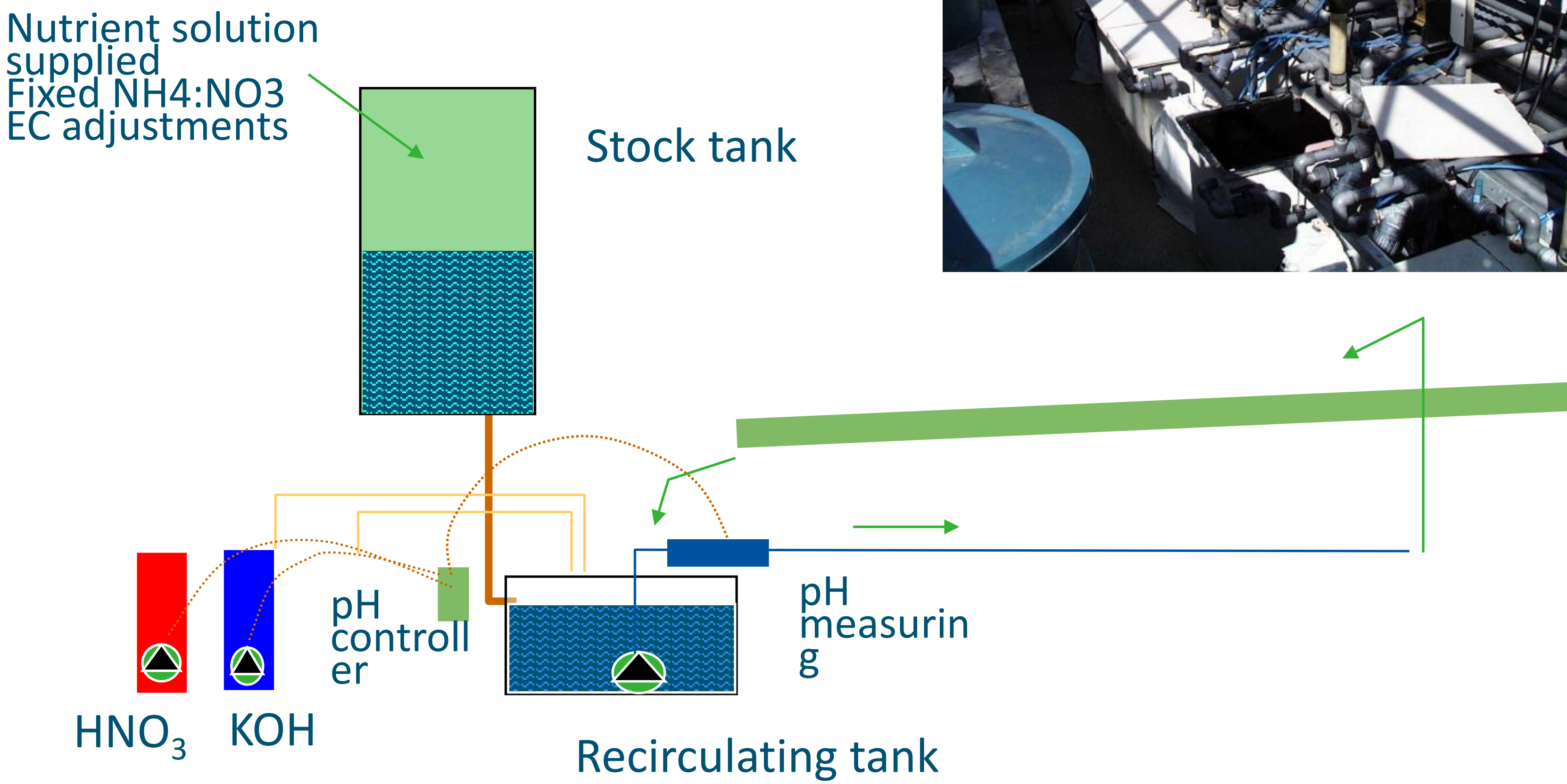
WAGENINGEN
UNIVERSITY & RESEARCH

Nutrient adjustments

	treatment											
	pH	NH_4	K	Ca	Mg	NO_3	SO_4	H_2PO_4	H^+	OH^-	*cations*	*anions*
1	4.5 - 5.0	0										
2	5.3 - 5.8	0	6.5	2.75	1	11.75	1	1.25	1		*15.0*	*15.0*
3	6.2 - 6.5	0										
4	4.5 - 5.0	1.5										
5	5.3 - 5.8	1.5	6.27	2.65	0.965	11.36	0.965	1.21		0.5	*15.0*	*15.0*
6	6.2 - 6.5	1.5										
7	4.5 - 5.0	3										
8	5.3 - 5.8	3	5.56	2.36	0.86	10.18	0.87	1.08		2	*15.0*	*15.0*
9	6.2 - 6.5	3										

WAGENINGEN
UNIVERSITY & RESEARCH

Schematic



WAGENINGEN
UNIVERSITY & RESEARCH

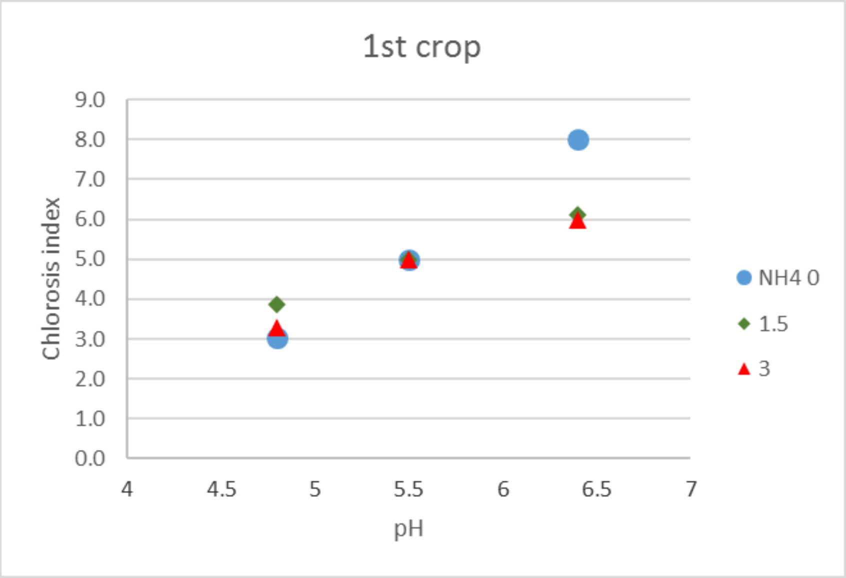
Chlorosis

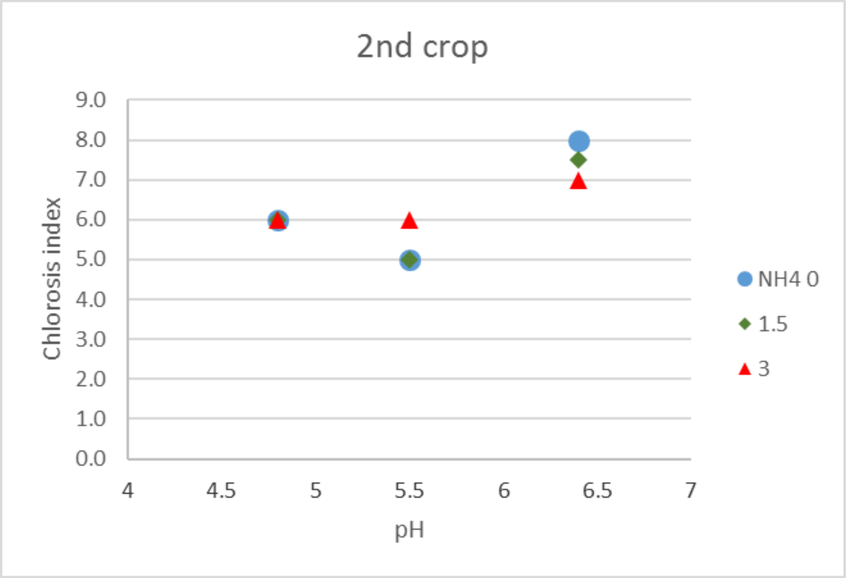
- Visual judgements

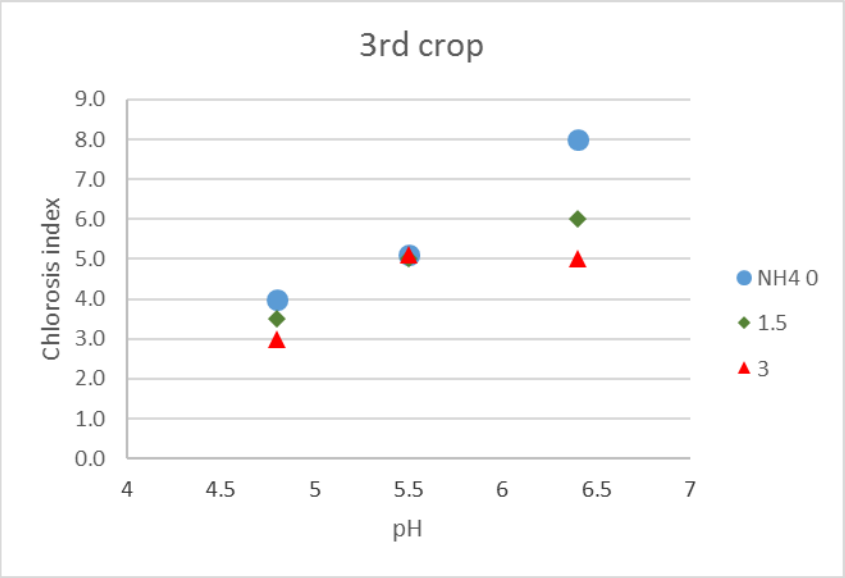
4 5 6 7

WAGENINGEN
UNIVERSITY & RESEARCH

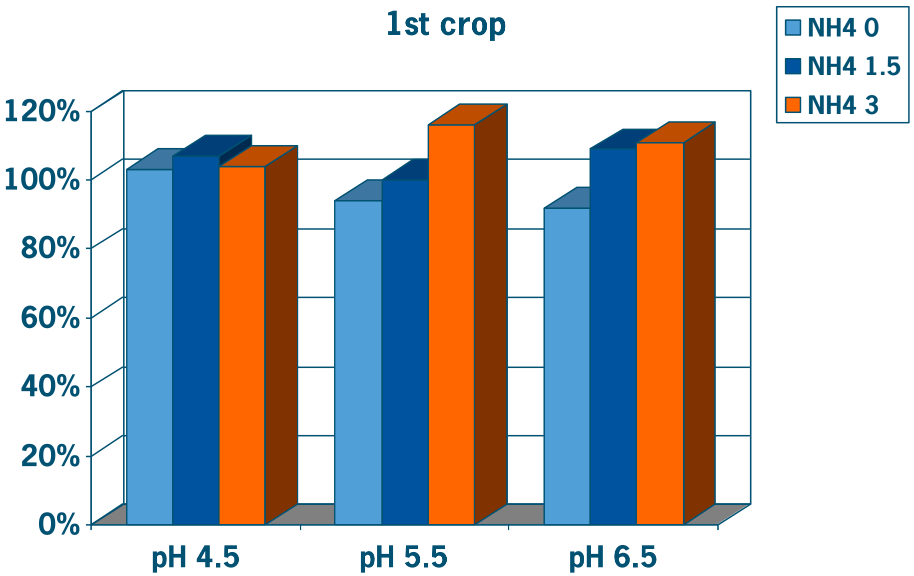
Chlorosis

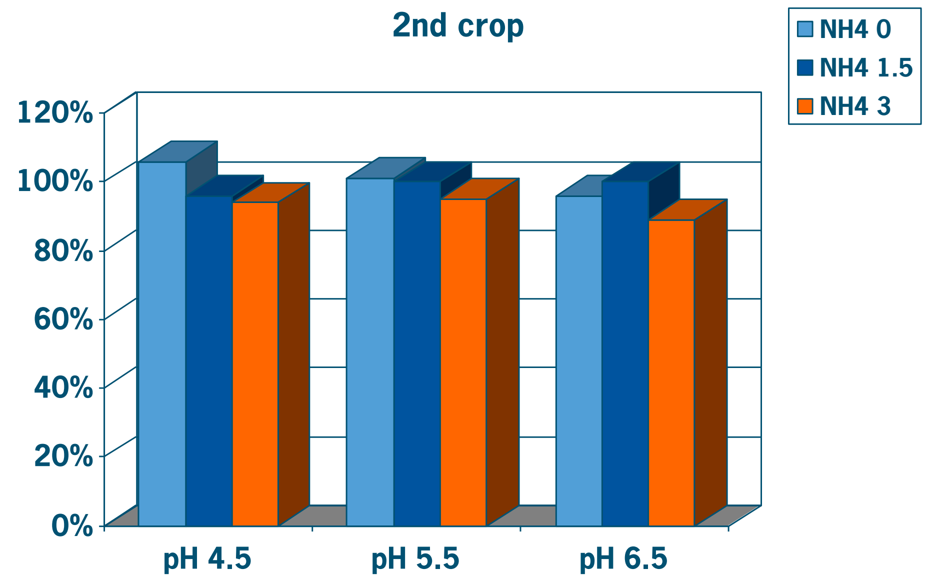

1st crop
Chlorosis index
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
4
4.5
5
5.5
6
6.5
7
pH
NH4 0
1.5
3

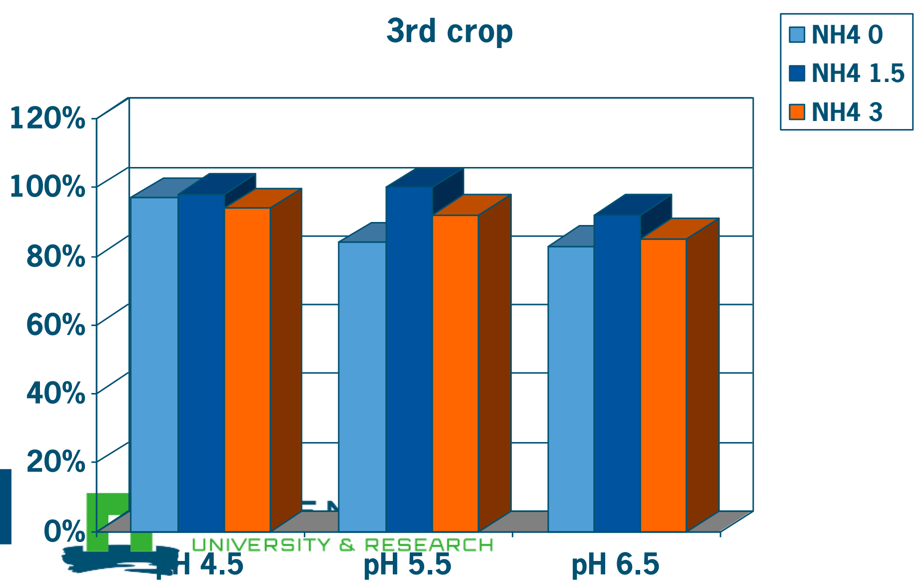

2nd crop
Chlorosis index
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
4
4.5
5
5.5
6
6.5
7
pH
NH4 0
1.5
3

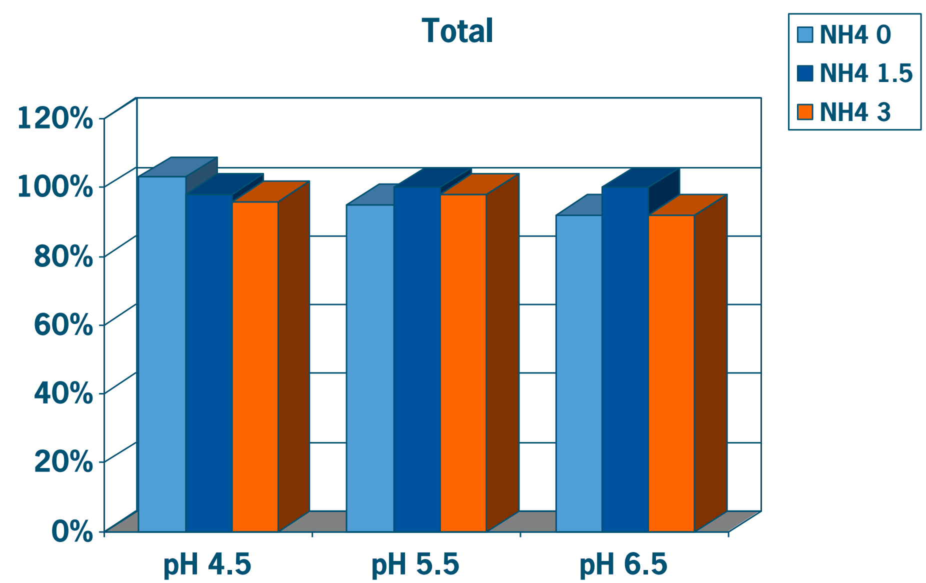

3rd crop
Chlorosis index
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
4
4.5
5
5.5
6
6.5
7
pH
NH4 0
1.5
3

Yield


1st crop
NH4 0
NH4 1.5
NH4 3
120%
100%
80%
60%
40%
20%
0%
pH 4.5
pH 5.5
pH 6.5

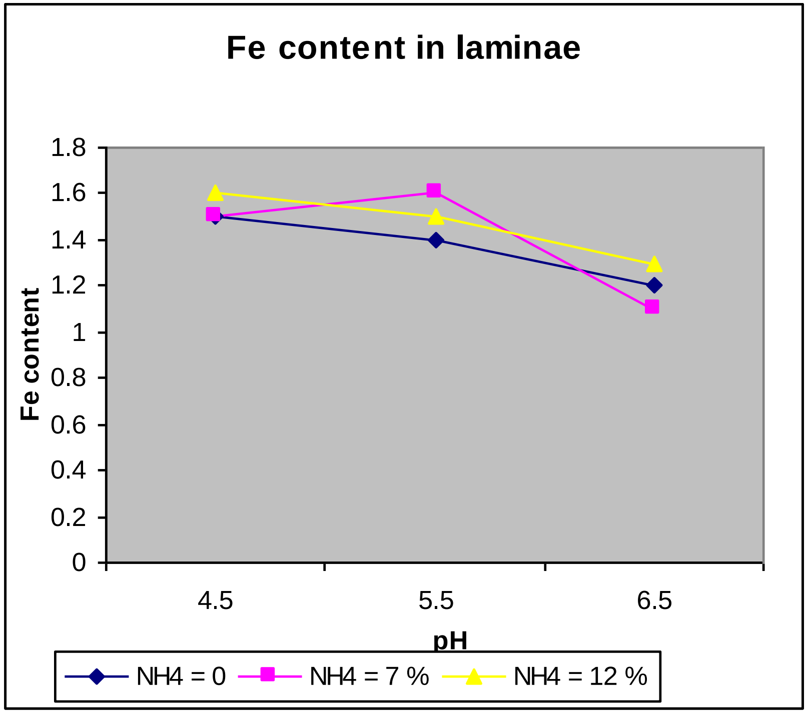

2nd crop
NH4 0
NH4 1.5
NH4 3
120%
100%
80%
60%
40%
20%
0%
pH 4.5
pH 5.5
pH 6.5

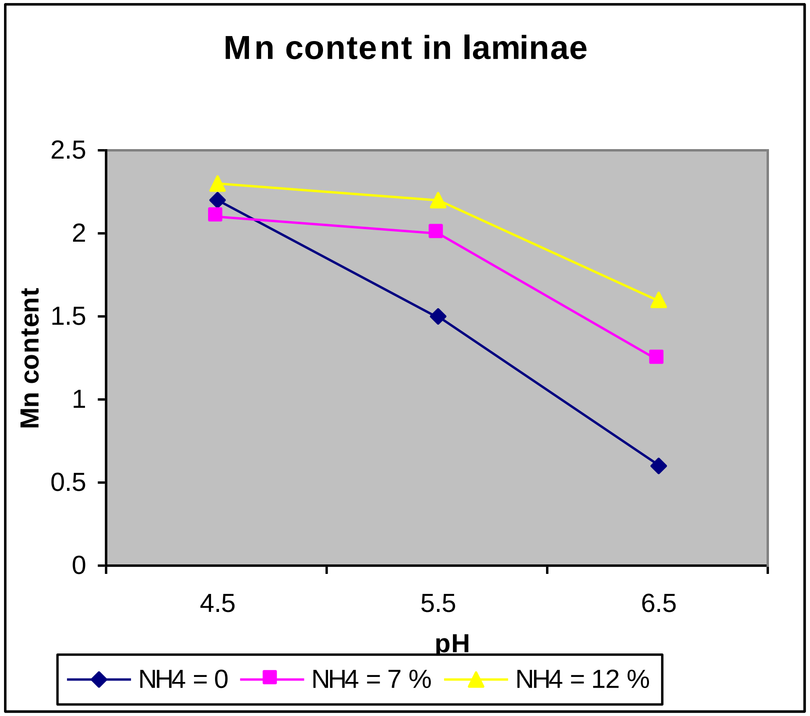

3rd crop
NH4 0
NH4 1.5
NH4 3
120%
100%
80%
60%
40%
20%
0%
pH 4.5
pH 5.5
pH 6.5


Total
NH4 0
NH4 1.5
NH4 3
120%
100%
80%
60%
40%
20%
0%
pH 4.5
pH 5.5
pH 6.5

Interaction between pH and NH_4

Effect on micro element uptake





WAGENINGEN
UNIVERSITY & RESEARCH

Interaction between pH and NH_4

Rose
chlorosis index:
0 = green,
10 = yellow

	NH4 supply		
pH	0	1.5	3
4.5 - 5.0	2.8	3.4	3.0
5.0 - 5.5			
6.0 - 6.5	6.3	6.4	4.2

Summary NH_4 : NO3 ratio trials

% NH4	Lettuce	Tomato	Cucumber	Sweet Pepper	Rose)*	Gerbera)*
0	100	100	100	100	100	100
5		102	101	98		108
7.5	100	98	108	102	110	120
10		101	110		117	
12	100	98	108	94	125	118
15					121	

)* Cultivars susceptible for chlorosis

NH_4 and corcky root / brown roots with tomato

WAGENINGEN
UNIVERSITY & RESEARCH

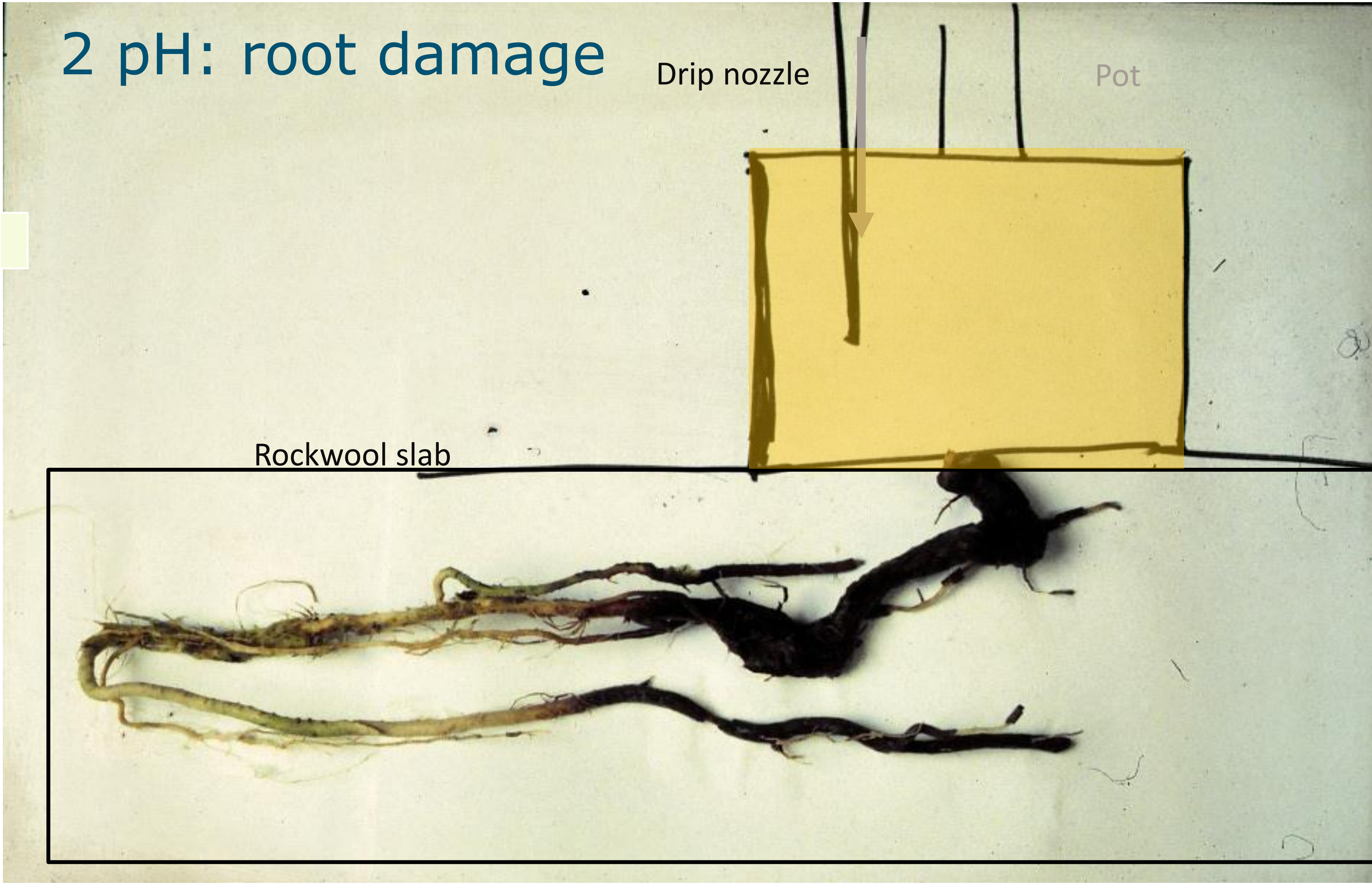
Results trial

pH	NH4	brown roots *	corcky root *	number of spores *
4.5	0	6	1.5	10
4.5	0	4	0.5	10
4.5	1.5	5	1	6
4.5	1.5	5	1	10
6.5	0	3	0.5	3
6.5	0	7	0.5	0
6.5	1.5	6	0	1.5
6.5	1.5	7	0	0

*** Index 0 - 10**

WAGENINGEN
UNIVERSITY & RESEARCH

2 pH: root damage



Other Literature

- Negative correlations for carotenoids (β-carotene and lycopene) and NO_3 in root environment
- No significant differences between conventional and organic tomatoes (Gravel et al, 2010)

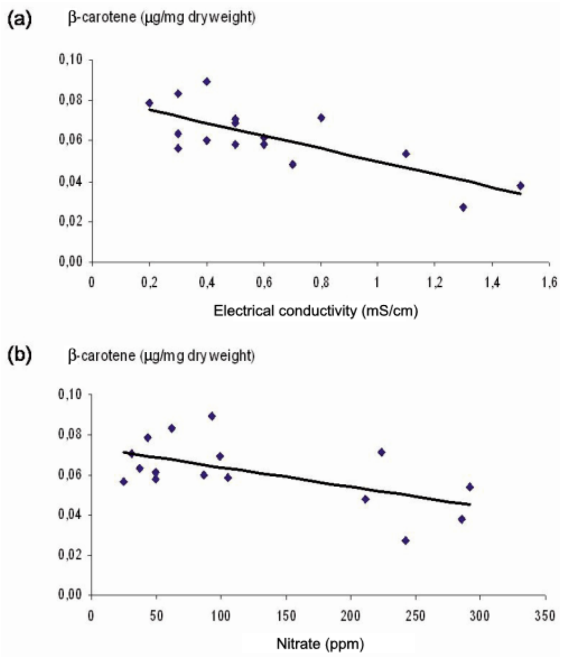


Figure 2. Correlation between β-carotene content in tomato fruits and electrical conductivity (EC) (a) or NO_3^- in the soil (b). β-carotene is negatively correlated with soil EC and NO_3^- content when all soil-bound systems are considered with correlation coefficients of –0.77 and –0.61, respectively.

WAGENINGEN UNIVERSITY & RESEARCH

Journal of the Science of Food and Agriculture

J Sci Food Agric **85**:1405–1414 (2005)
DOI: 10.1002/jsfa.2127

Nitrogen form affects yield and taste of tomatoes

Anuschka Heeb,[1]* Bengt Lundegårdh,[1] Tom Ericsson[2] and Geoffrey P Savage[3,4]

Table 1. Nitrogen form, chloride and sulphur levels in the five treatments

Treatment	$NO_3^-:NH_4^+$ ratio	Cl level	S level[a]
I	4:1	No	Low
II	1:4	High	Intermediate
III	1:4	Intermediate	High
IV	Organic (chicken manure etc)	—	—
V	Organic (grass and clover mulch)	—	—

[a] To balance the positive/negative ions of the nitrogen form.

Table 8. Taste test results (means ± SE; scores on a 1–13 scale). Treatments as in Table 1

Treatment	Firmness		Sweetness		Acidity		Flavour intensity		Flavour duration		Overall acceptance	
I	5.9b	±0.26	4.9b	±0.26	3.9c	±0.23	4.6c	±0.27	4.8c	±0.24	4.8b	±0.27
II	6.4ab	±0.23	6.5a	±0.21	5.2b	±0.25	6.4b	±0.25	6.5b	±0.24	7.1a	±0.26
III	6.4ab	±0.23	6.6a	±0.21	5.5b	±0.23	7.3a	±0.25	7.2ab	±0.25	7.6a	±0.27
IV	6.2ab	±0.24	6.5a	±0.23	5.7b	±0.24	7.1ab	±0.25	6.9b	±0.27	7.7a	±0.27
V	6.9a	±0.23	5.9a	±0.23	7.2a	±0.27	7.5a	±0.25	8.1a	±0.27	8.0a	±0.28
($p < 0.05$)	*		****		****		****		****		****	

Values with different letters in each column are significantly different.
NS, not significant; * 0.05; ** 0.01; *** 0.001; **** <0.0001.

In conclusion:
fruit vegetables in soil-less systems

- EC important, NO_3 can be replaced partly by Cl, SO_4
  - Cl –> less BER (more Gold Speck)
    - *More Cl reduce shelf life*
  - Too low N, shelf life, taste will decrease
- N-form.
  - Low volume/buffer, pH instable, NH_4/NO_3 ratio limited.
- Increase NH_4 :
  - Risk of brown / corcky root, less chlorosis, i
  - Improve taste ? need further investigation

WAGENINGEN
UNIVERSITY & RESEARCH

Nutrient solution

$NH_4 : NO_3$ ratio	
Tomato	0.07 - 1
Cucumber	0.08 - 1
Melon	0.07 - 1
	0.00 - 1)*
Rose	0.1 - 1
Carnation	0.08 - 1

example

EC	1.3
	mmol/l
NH_4	1
K	**6.5**
Ca	**2.75**
Mg	**1**
NO3	**10.25**
Cl	**0.5**
SO4	1.5
H2PO4	1.25
Si	0
	umol/l
Fe	**15**
Mn	**10**
Zn	4
B	**20**
Cu	**0.75**
Mo	**0.5**

End slide or section heading

Tekst