cajamar CAJA RURAL

Adoption of soilless culture in Almeria (Spain) and local research related to these growing systems

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FUNDACIÓN cajamar

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Almeria location

Typical growing system: enarenado and parral-type greenhouse

Evolution of soilless culture in Almeria

NFT (1980)

Substrate bags (80's)

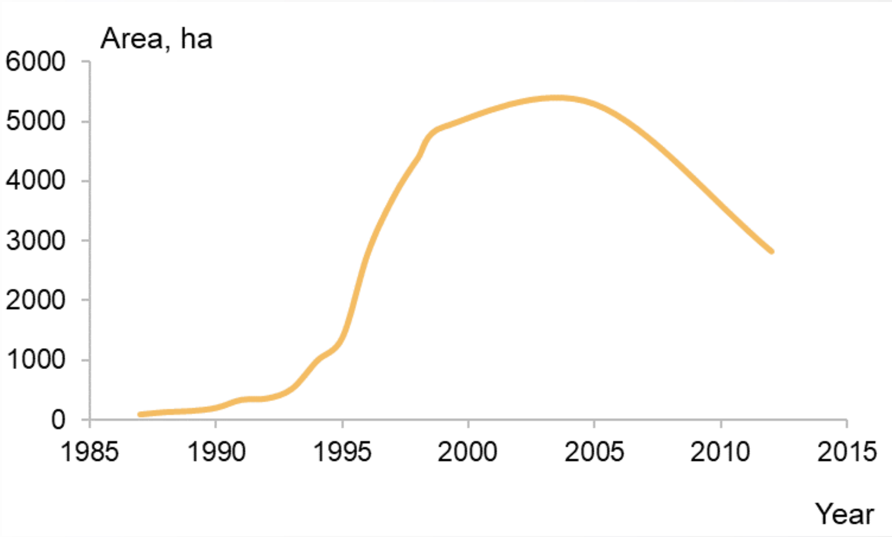
Evolution of soilless culture in Almeria. Alternative soilless systems

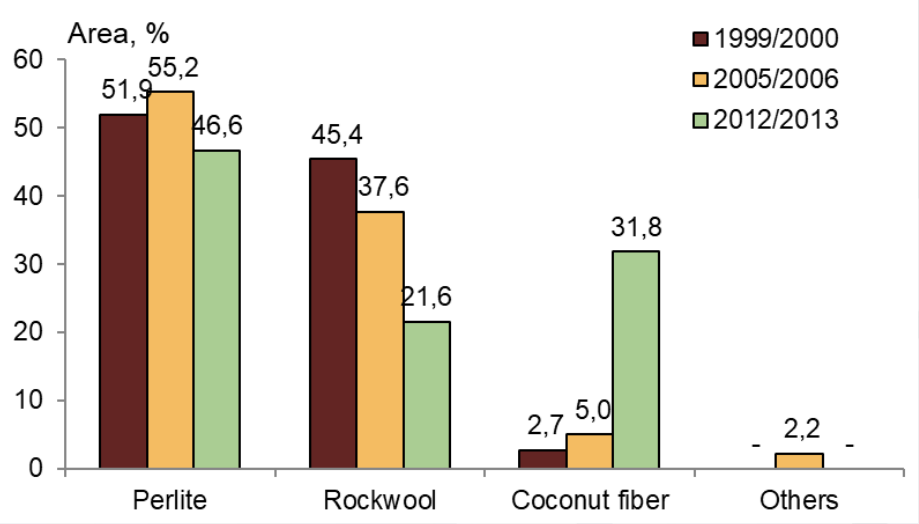
QUASH system

Stratified perlite in polystyrene containers

New Growing System (NGS)

Evolution of soilless culture in Almeria and percentage distribution of the different substrates

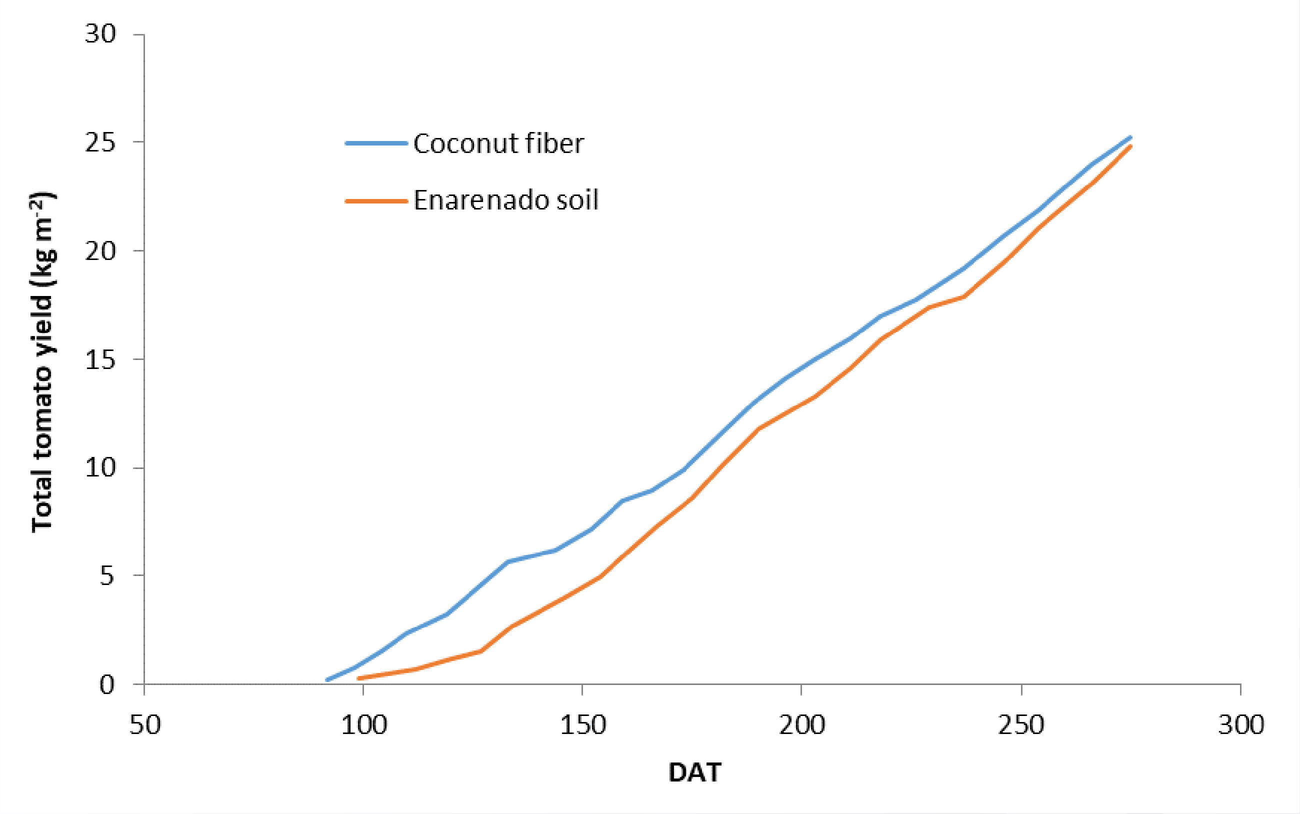




García *et al*. (2016)

Comparison between substrate and 'enarenado' cropping

Parameter	Unit	Enarenado soil	Coconut fiber
Nitrogen supply	Kg N/ha	790.3	1222.5
Phosphorus supply	Kg P2O5/ha	709.6	886.1
Potassium supply	Kg K2O/ha	1214.7	2545.1



Mixed system substrate-soil

http://www.cocopeatfertilizer.com/fibra-de-coco/sistema-enficonado

Substrate reuse

Substrates can be reused for several years in order to reduce the production cost and the waste generation. Hence, it is important to know how long it is possible to reuse the substrate without having problems affecting the crop. A study was carried out with rockwool and perlite to study the dynamics of the physical properties and the crop response.

Substrate reuse (Acuña *et al*., Scientia Horticulturae 160: 139-147)

Physical properties were evaluated in rockwool of the following ages:

- New rockwool (first use)
- One year of use: pepper + melon
- Two years of use: cucumber + melon (year 1); tomato (year 2)
- Three years of use: cucumber + melon (year 1); tomato (year 2) pepper + melon (year 3)

Horizontal-type rockwool slabs of 1 m x 0.15 m x 0.1 m (Med Horizontal) were used in the study.

Substrate reuse (Acuña *et al*., Scientia Horticulturae 160: 139-147)

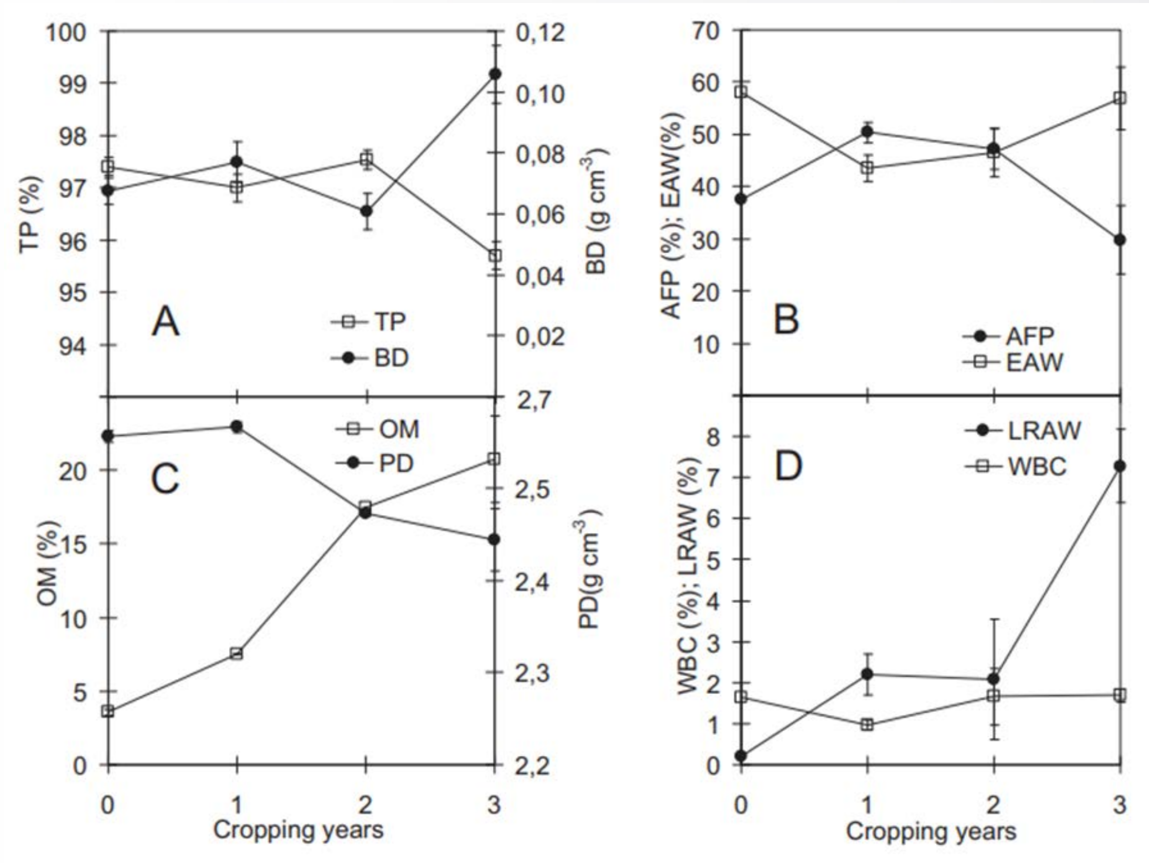
Physical properties were evaluated in perlite of the following ages:

- New perlite (first use)
- One year of use: pepper + melon
- Four years of use: pepper + watermelon (years 1 and 2); pepper + melon (years 3 and 4)
- Five years of use: pepper + watermelon (years 1 and 2); pepper + melon (years 3, 4 and 5)

B12-type perlite bags of 36 liters capacity were used in the study. At the beginning of each cropping year, the perlite located around the old roots of each plant in the reused growbags was extracted with a cylinder (Ø 0.1 m) and replaced by new perlite.

Substrate reuse (Acuña *et al*., Scientia Horticulturae 160: 139-147)

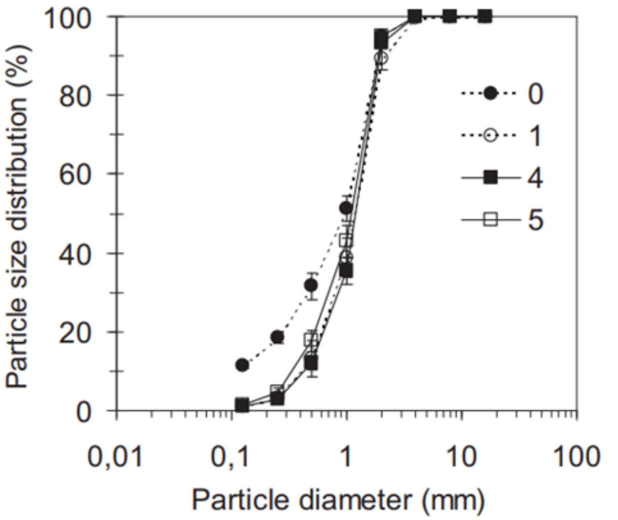
Some compactation was detected in the rockwool slabs after 3 years. Air-filled porosity was in the recommended limit (30%) in that moment. It is not advisable to extent cropping for a fourth year.

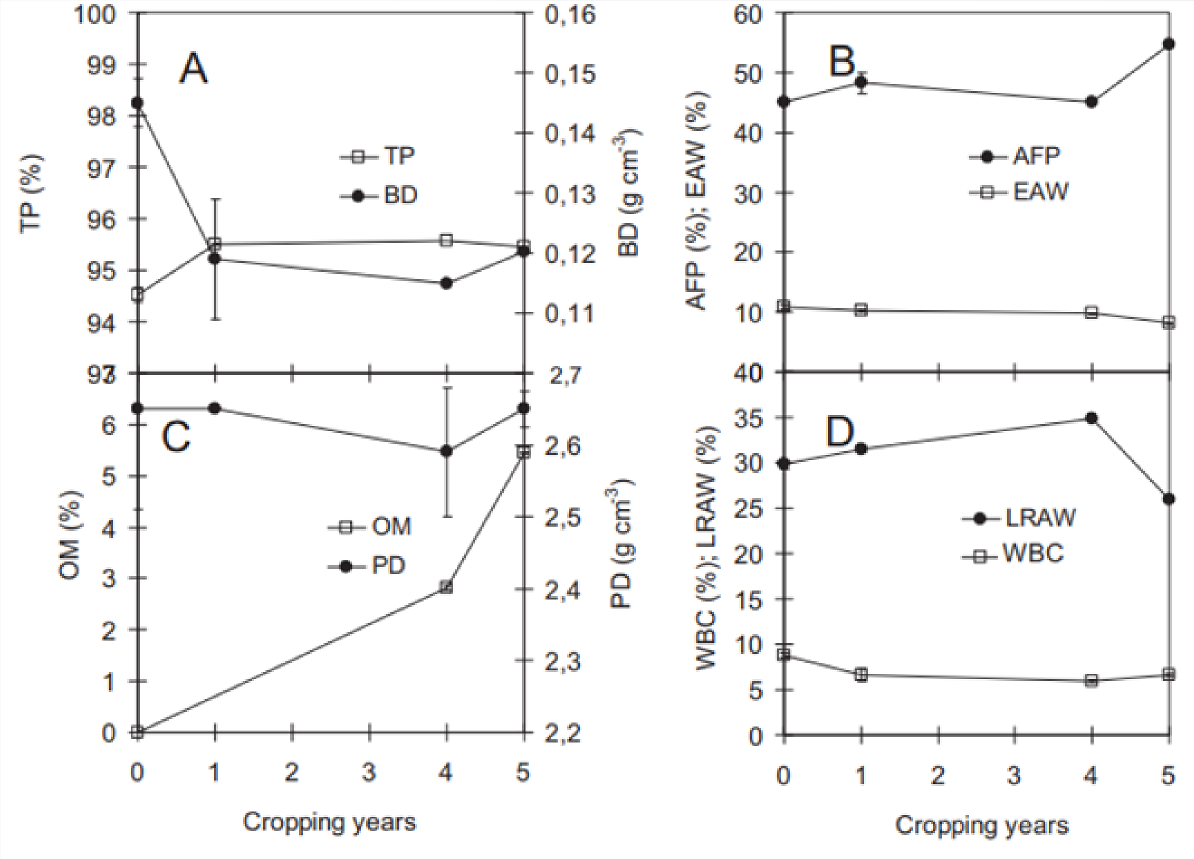


Compactation of the slab after 3 years of use

Substrate reuse (Acuña *et al*., Scientia Horticulturae 160: 139-147)

During the first cropping year, the perlite grow-bag lost most of the finer particles, especially those with a diameter lower than 0.5 mm, whereas the relative size distribution of perlite particles and the physical properties remained quite steady over the following cropping years.





Substrate reuse (Acuña *et al*., Scientia Horticulturae 160: 139-147)

In general, significant differences were not detected in the fresh weight of total and marketable sweet pepper or melon fruits grown on new (N) and reused (R) rockwool slabs. By contrast, total yield of pepper was higher in new perlite, whereas that of melon was higher in reused perlite.

Fresh weight of total, marketable, first and second class fruits ($kg\ m^{-2}$), and yield components [fruit number ($fruits\ m^{-2}$) and mean fruit weight ($g\ fruit^{-1}$)] at the end of the sweet pepper and melon crop cycles grown on new (N) and reused (R) rockwool slabs (2003/2004 season) and perlite grow-bags (2004/2005 season).

Crops and substrate	Substrate type	Fresh fruit weight				Yield components	
		Total	Marketable	First class	Second class	Fruit number	Fruit weight
Sweet pepper (rockwool)	N	9.4a	8.5a	5.8a*	2.7a	44.6a	190a
	R	9.8a	8.8a	6.4b	2.4a	45.0a	195b
Melon (rockwool)	N	6.1a	6.0a	4.9a	1.1a	9.7a	614a
	R	5.9a	5.9a	5.0a	0.9a	9.3a	630a
Sweet pepper (perlite)	N	8.6b	7.7a	5.6b	2.0a	38.2a	200a
	R	8.2a	7.4a	5.2a	2.2a	36.9a	202a
Melon (perlite)	N	5.6a	5.4a	4.8a	0.6a	7.5a	718a
	R	5.9b	5.7b	5.2b	0.5a	7.9a	728a

* Values with different letters within the same column are significantly different ($P < 0.05$).

Stress by oxygen deficiency

Roots need oxygen for respiration. In most of the plants, oxygen reaches the roots through the growing media by diffusion. Oxygen diffusion rate (ODR) is much higher in air than water and it is related to the air capacity of the substrate. Theoretically, ODR is not a limiting factor with an air capacity of the substrate higher than 30%, but in practical conditions ODR can be reduced because of the excessive and frequent irrigations, the plastic wrapping the substrate, the high root development and the modification of the physical properties in reused substrates.

A study was carried out to evaluate the dynamics of the oxygen content of the substrate solution and the response of soilless-grown vegetable crops to oxyfertigation.

Evaluation of oxyfertigation

Dissolved oxygen (DO) in the substrate solution was periodically determined by extracting the solution and using an oxymeter.

Evaluation of oxyfertigation (Bonachela *et al*., Span. J. Agric. Res. 8(4): 1231-1241)

Values of DO in the nutrient solution supplied were higher for the oxygen-enriched treatment than for the non-enriched one throughout the four studied crop cycles. However, no significant differences in the substrate DO values were found between oxygen treatments, although they were slightly higher for the oxygen-enriched treatments.

Table 1. Average seasonal dissolved oxygen values (mg L^{-1}) in the nutrient and substrate solution of sweet pepper and melon crops grown with (+O_2) and without (O_2) oxygen enrichment of the nutrient solution. Almería coast, southeast Spain

Oxygen treatments		2003/04 season (rockwool slabs)		2004/05 season (perlie slabs)	
		Sweet pepper	Melon	Sweet pepper	Melon
Nutrient solution	+O_2	23.8[b]	21.1[b]	21.8[b]	21.7[b]
	O_2	4.0[a]	3.7[a]	4.2[a]	3.7[a]
Substrate solution	+O_2	6.3[a]	3.1[a]	4.9[a]	2.8[a]
	O_2	6.2[a]	3.0[a]	4.4[a]	2.6[a]

Values with different letter within the same column and solution type are significantly different ($p<0.05$).

Evaluation of oxyfertigation (Bonachela *et al*., Span. J. Agric. Res. 8(4): 1231-1241)

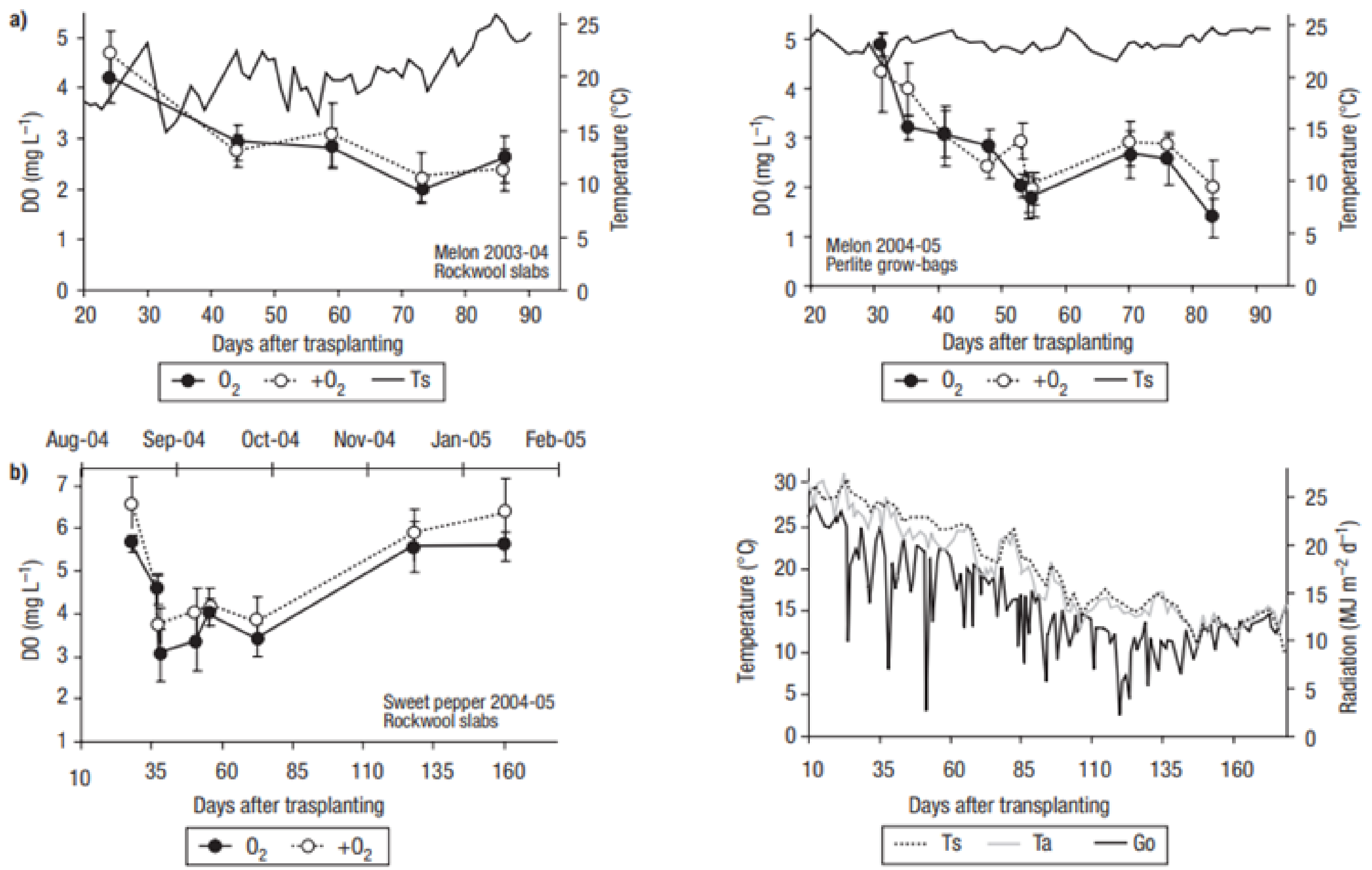


Figure 1. a) Seasonal dynamics of dissolved oxygen (DO) in the substrate solution (mean ± standard error) and substrate temperature (Ts) values of melon crops grown with (+O_2) and without (O_2) oxygen enrichment. b) Seasonal dynamics of substrate DO, substrate and greenhouse air (Ta) temperatures and outside solar radiation (Go) values of a sweet pepper crop grown on perlite grow-bags with (+O_2) and without (O_2) oxygen enrichment.

Evaluation of oxyfertigation (Bonachela *et al*., Span. J. Agric. Res. 8(4): 1231-1241)

The seasonal evolution of the total fresh fruit weight of sweet pepper crops was similar for both oxygen treatments in the two substrates. However, the yield response of melon crops to oxyfertigation depended on the type of substrate. No significant differences were found between oxygen treatments for any productivity parameter for the melon grown on perlite grow-bags (Table 3), whereas a significant 7% increase in total and marketable yield, associated with a higher fruit number, was observed for the oxygen enriched treatment grown on rockwool slabs.

Table 3. Fresh weight of total, marketable, first and second class fruits (kg m^{-2}), and yield components [fruit number (fruits m^{-2}) and mean fruit weight (g $fruit^{-1}$)] at the end of the sweet pepper and melon crop cycles grown with ($+O_2$) and without (O_2) oxygen enrichment

Crops	Oxygen treatment	Fresh fruit weight				Yield components	
		Total	Marketable	First class	Second class	Fruit number	Fruit weight
Sweet pepper (rockwool)	$+O_2$	9.6[a]	8.6[a]	6.1[a]	2.5[a]	44.2[a]	195[a]
	O_2	9.6[a]	8.6[a]	6.0[a]	2.6[a]	45.4[a]	190[a]
Sweet pepper (perlite)	$+O_2$	8.4[a]	7.7[a]	5.5[a]	2.2[a]	37.8[a]	203[a]
	O_2	8.6[a]	7.7[a]	5.4[a]	2.3[a]	39.5[a]	194[a]
Melon (rockwool)	$+O_2$	6.1[b]	6.1[b]	5.2[b]	0.9[a]	10.0[b]	616[a]
	O_2	5.7[a]	5.7[a]	4.7[a]	1.0[a]	9.0[a]	634[a]
Melon (perlite)	$+O_2$	5.7[a]	5.5[a]	4.8[a]	0.7[a]	7.6[a]	723[a]
	O_2	5.6[a]	5.5[a]	5.0[a]	0.5[a]	7.5[a]	733[a]

Values with different letter within the same column and crop cycle are significantly different ($p < 0.05$).

Oxygen enrichment of the irrigation water in the pond (Bonachela *et al*., Irrigation Science 31(4): 769-780)

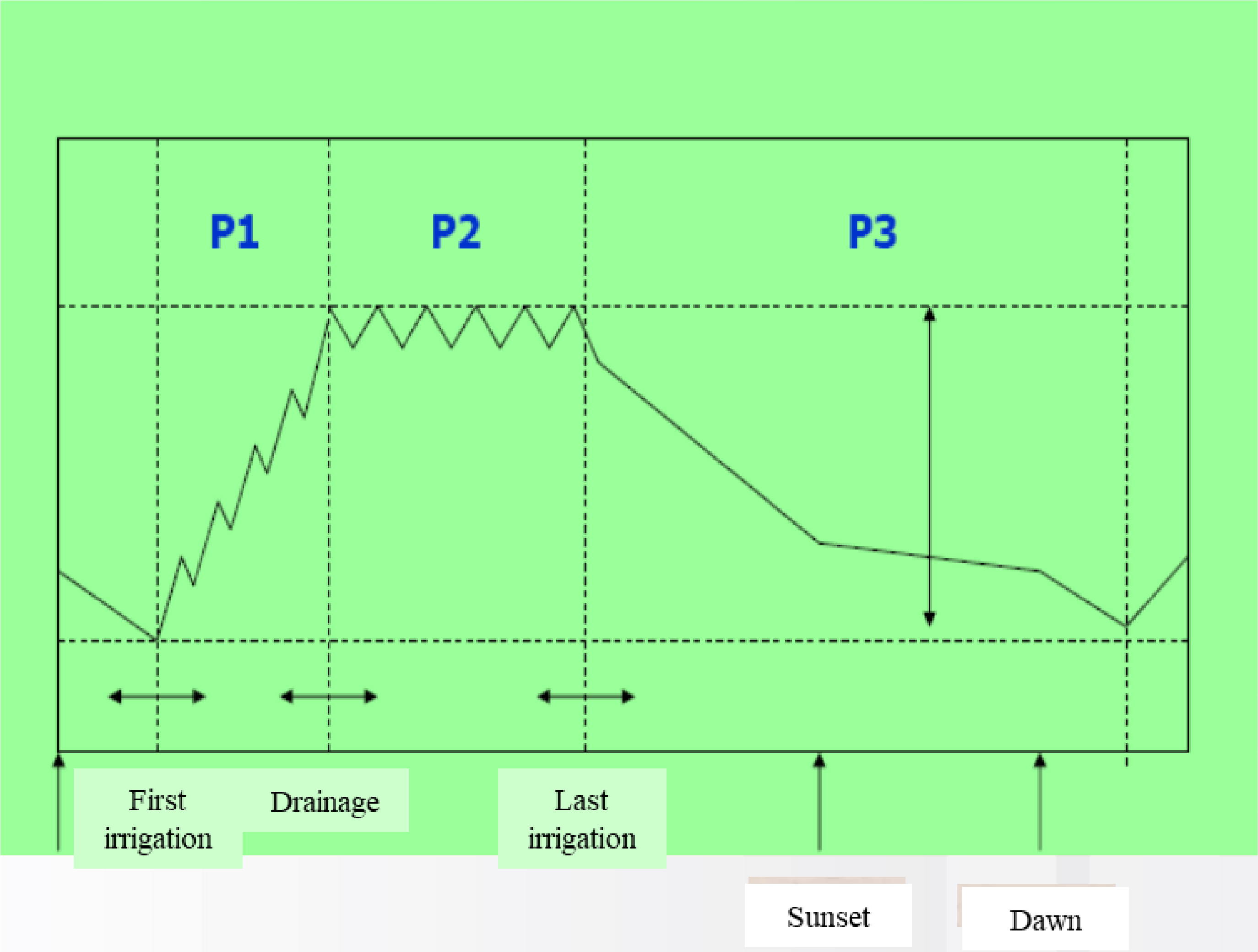
The development of certain aquatic plants, like *Chara*, in the pond can promote a high dissolved oxygen concentration and a lower microalgae development in the water in an easy and economic way.

Table 5 Mean (±1SEM) values of water quality parameters of uncovered ponds fed with groundwater/surface waters: (a) ponds with *vs.* without SAV; (b) ponds with predominance of *Potamogeton pectinatus* vs. ponds with predominance of *Chara* spp.; (c) ponds with SAV treated with biocides *vs.* untreated ones

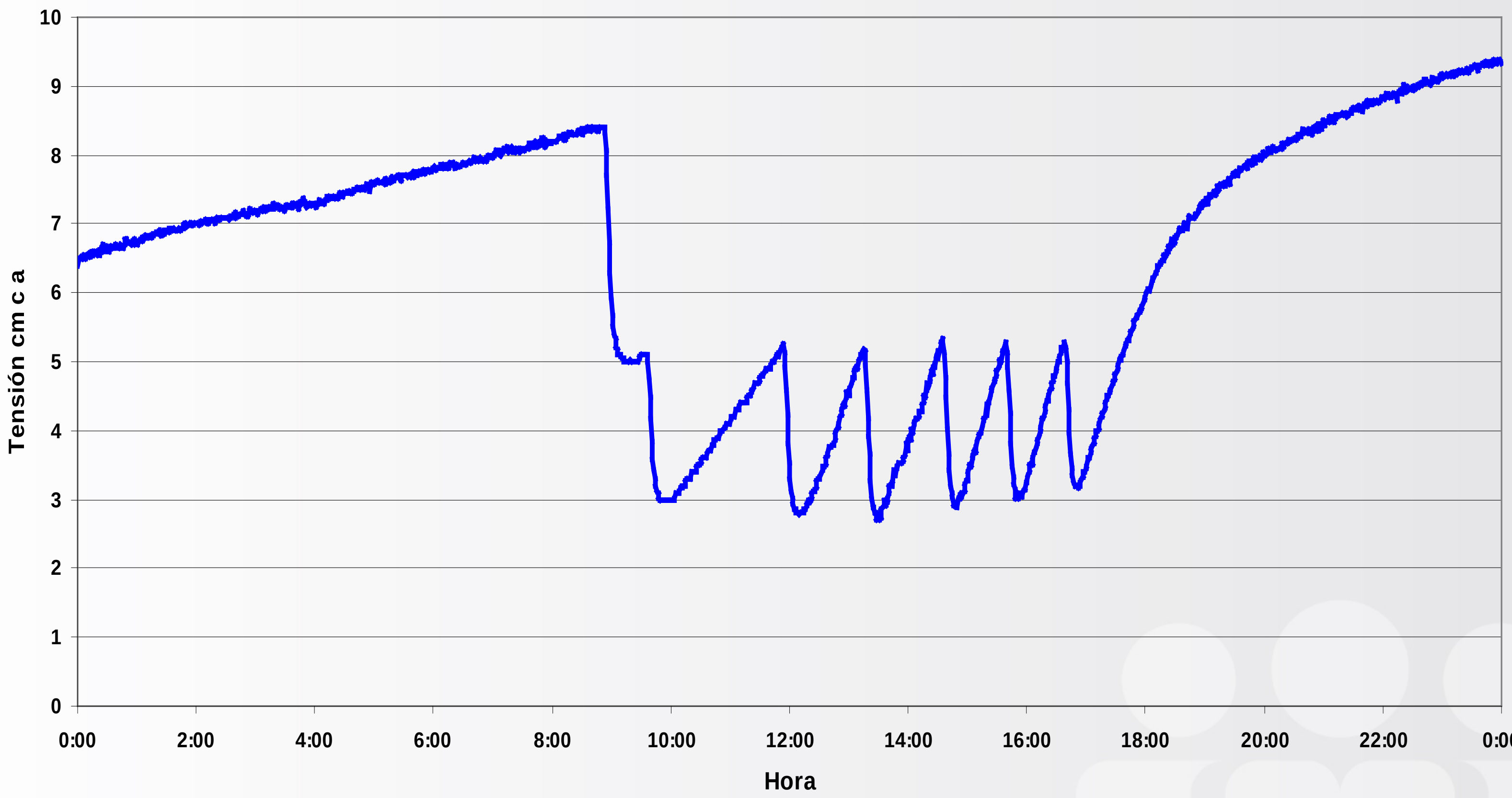
	(a) SAV presence		(b) SAV types		(c) Biocides usage	
	With SAV ($N = 32$)	Without SAV ($N = 30$)	*Potamogeton* ($N = 16$)	*Chara* ($N = 14$)	Treated ($N = 19$)	Untreated ($N = 13$)
pH	8.2 ± 0.1 a	8.1 ± 0.1 a	8.3 ± 0.1 a	8.2 ± 0.2 a	8.4 ± 0.2 a	8.1 ± 0.1 a
EC (dS m^{-1})	2.1 ± 0.2 a	2.0 ± 0.2 a	2.3 ± 0.3 a	1.8 ± 0.3 a	2.2 ± 0.3 a	1.9 ± 0.3 a
DO (%)	120.9 ± 5.8 a	106.6 ± 6.5 a	117.6 ± 9.4 a	120.5 ± 7.0 a	119.8 ± 6.5 a	122.6 ± 11.1 a
TDS (g L^{-1})	1.1 ± 0.1 a	1.1 ± 0.1 a	1.2 ± 0.2 a	1.0 ± 0.2 a	1.1 ± 0.2 a	1.2 ± 0.2 a
TN (mg L^{-1})	2.6 ± 0.6 a	4.7 ± 1.1 a	1.6 ± 0.1 a	3.7 ± 1.3 a	2.8 ± 1.0 a	2.3 ± 0.5 a
TP (mg L^{-1})	0.1 ± 0.0 a	0.1 ± 0.0 a	0.1 ± 0.0 a	0.1 ± 0.0 a	0.1 ± 0.0 a	0.0 ± 0.0 a
SRP (μg L^{-1})	157.5 ± 142.3 a	36.0 ± 23.3 a	307.1 ± 293.4 a	19.3 ± 9.0 a	268.5 ± 246.7 a	7.0 ± 1.9 a
NO_3^- (mg L^{-1})	1.4 ± 0.5 a	3.4 ± 1.5 a	0.5 ± 0.1 a	2.4 ± 1.0 a	1.4 ± 0.8 a	1.4 ± 0.5 a
NO_2^- (mg L^{-1})	0.1 ± 0.0 a	0.1 ± 0.1 a	0.0 ± 0.0 a	0.1 ± 0.0 a	0.1 ± 0.0 a	0.0 ± 0.0 a
NH_4^+ (mg L^{-1})	0.1 ± 0.0 a	0.1 ± 0.0 a	0.1 ± 0.0 a	0.1 ± 0.0 a	0.1 ± 0.0 a	0.1 ± 0.0 a
HCO_3^- (mg L^{-1})	159.6 ± 12.3 a	163.0 ± 13.5 a	155.6 ± 16.9 a	174.0 ± 18.4 a	144.6 ± 17.4 a	180.2 ± 17.1 a
CO_3^{2-} (mg L^{-1})	20.3 ± 6.7 a	8.2 ± 2.5 a	25.4 ± 12.5 a	12.0 ± 3.7 a	25.5 ± 11.4 a	14.3 ± 3.4 a
TSS (mg L^{-1})	9.2 ± 2.3 a	10.3 ± 1.3 a	10.4 ± 4.4 a	8.6 ± 2.1 a	12.3 ± 3.8 a	4.8 ± 0.8 b
Chl *a* (μg L^{-1})	7.2 ± 1.8 b	23.2 ± 7.1 a	6.7 ± 1.4 a	7.8 ± 4.1 a	9.1 ± 3.1 a	4.8 ± 0.7 a
Cu^{2+}(mg kg^{-1}) in sediment	917 ± 298 b	3,774 ± 1,202 a	2,271 ± 770 a	241 ± 64 b	1,721 ± 653 a	485 ± 283 b

Mean values with a different letter in the same row of each section (a, b or c) are significantly different ($P < 0.05$). *SEM* Standard error of mean, *N*: Number of sampled ponds per treatment

Irrigation management

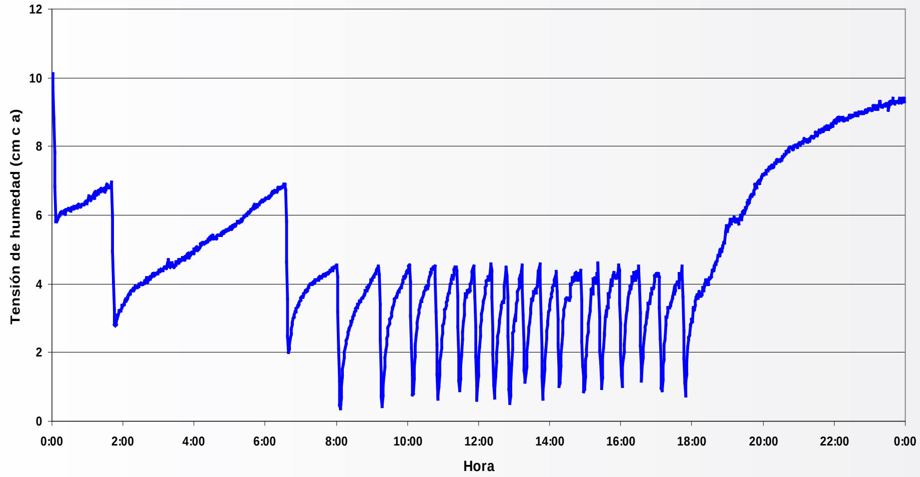


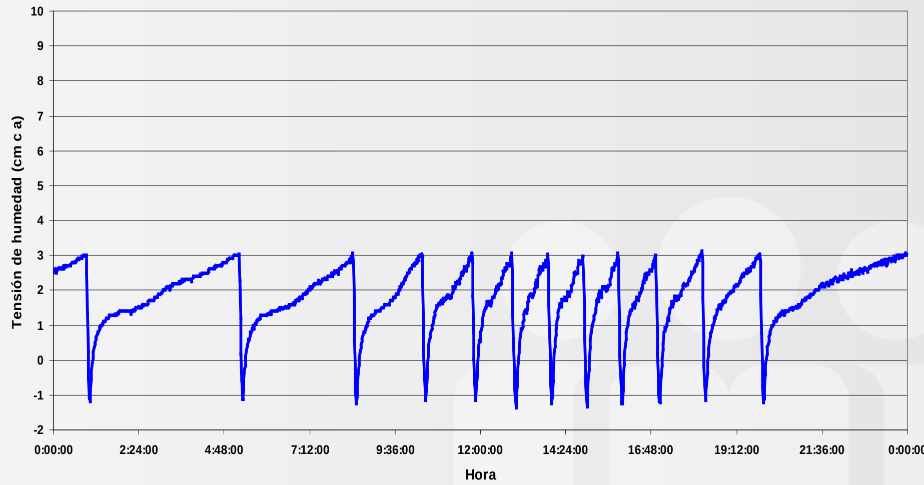
Hydraulic conductivity as a limiting factor



Terés *et al*. (2000)

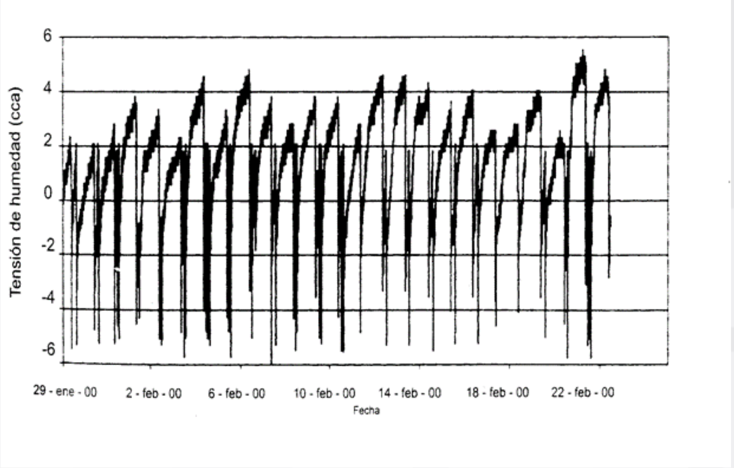
How to solve limiting hydraulic conductivity





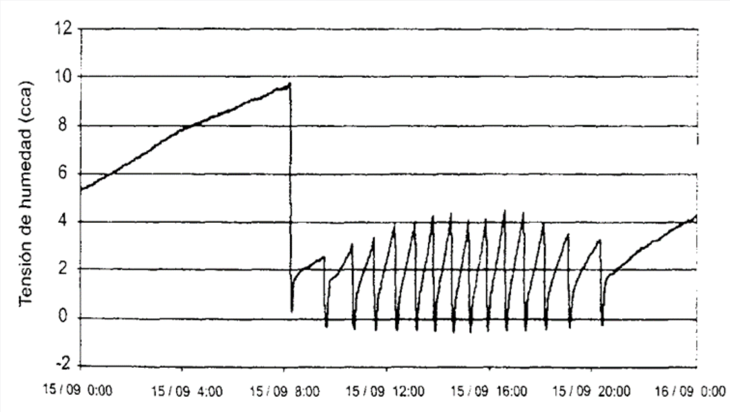
Terés *et al*. (2000)

Automatic irrigation by measuring substrate water potential



Terés *et al*. (2000)

Automatic irrigation by using a demand tray



Terés *et al*. (2000)

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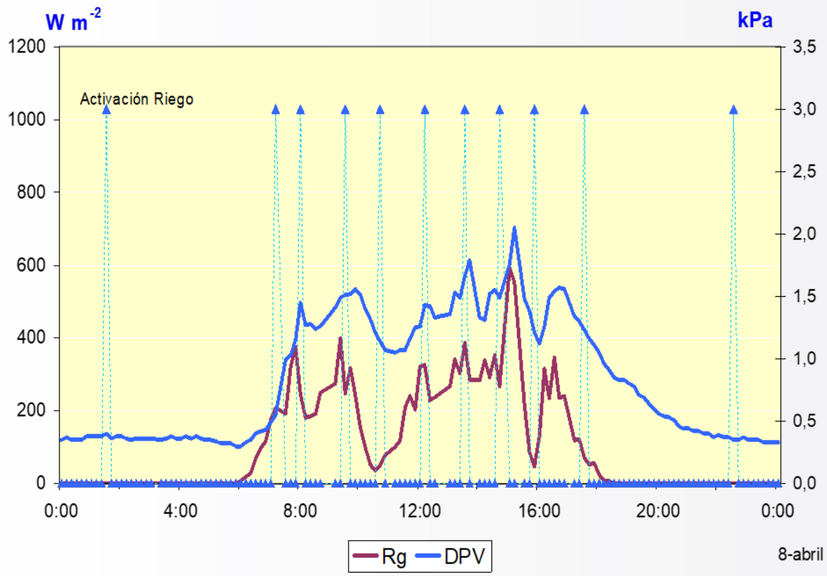
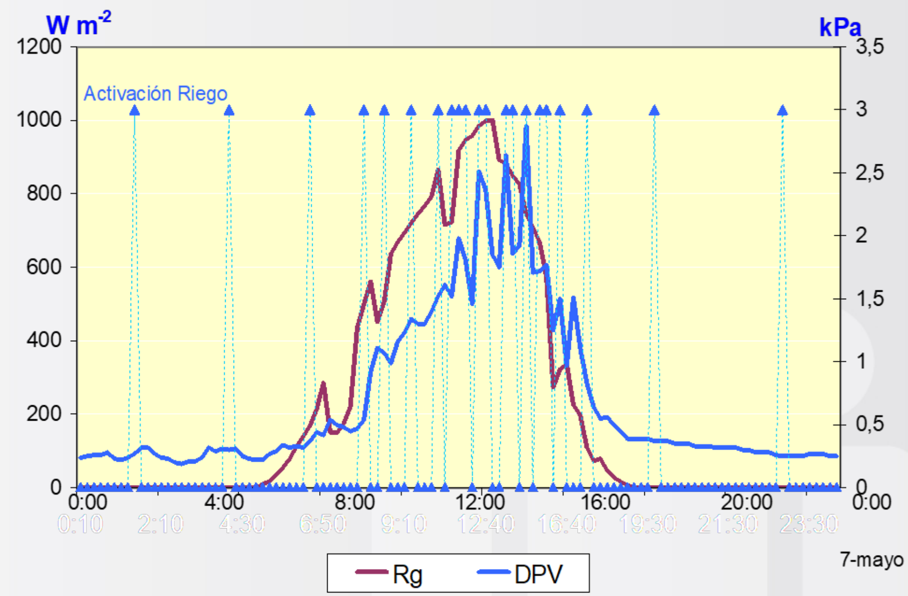
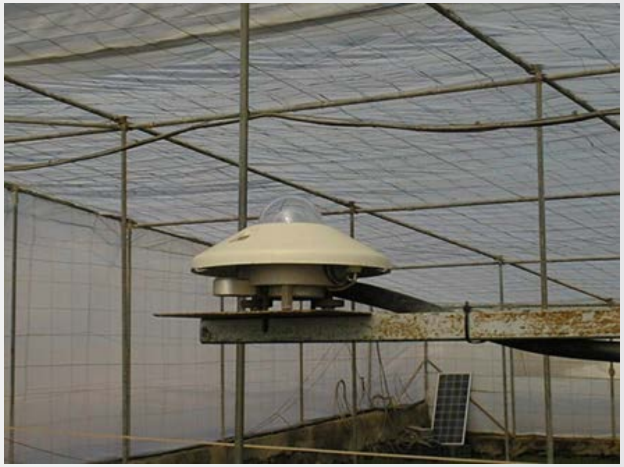
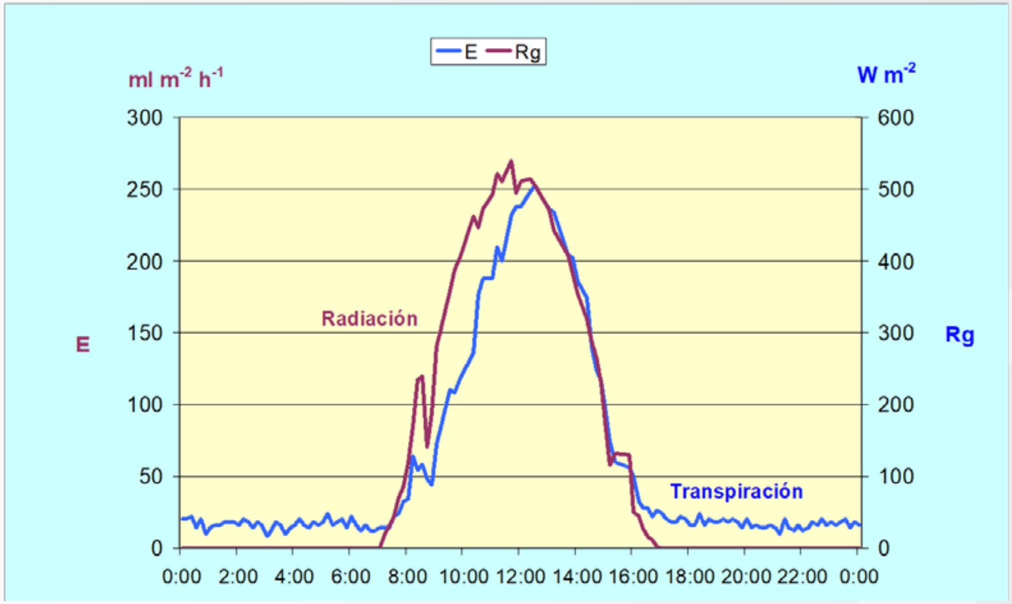


Medrano *et al*. (2008)



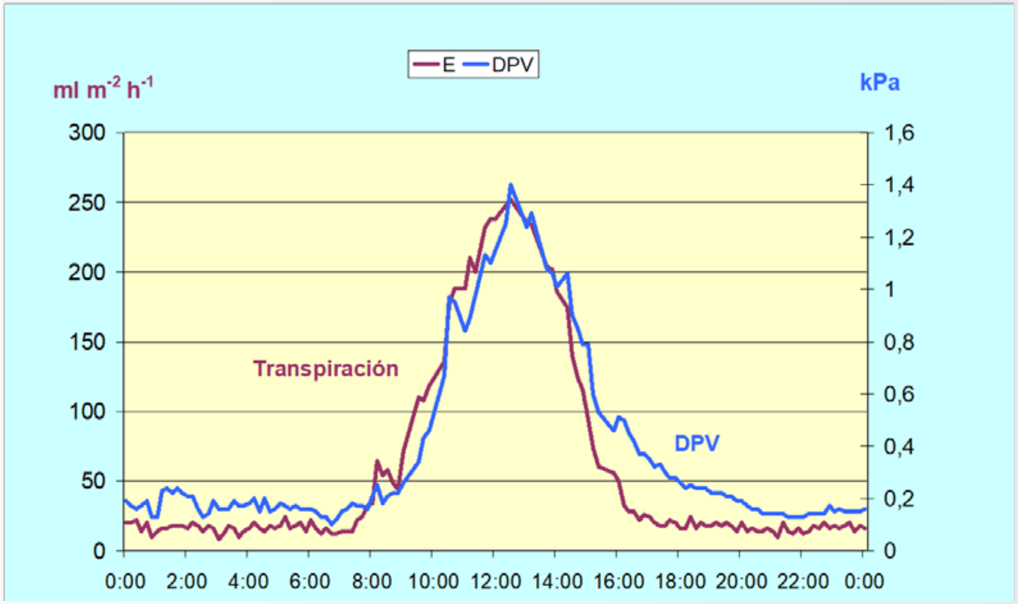
Automatic irrigation by measuring radiation



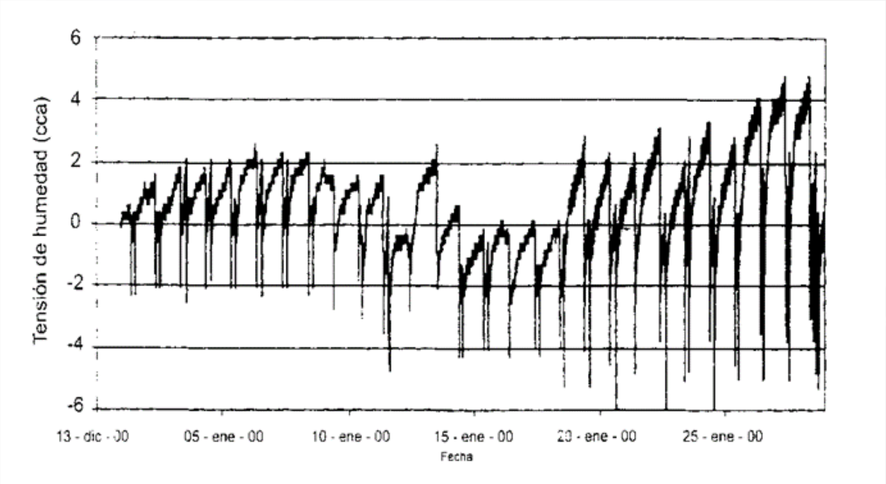


Medrano *et al*. (2008)

Automatic irrigation by measuring radiation

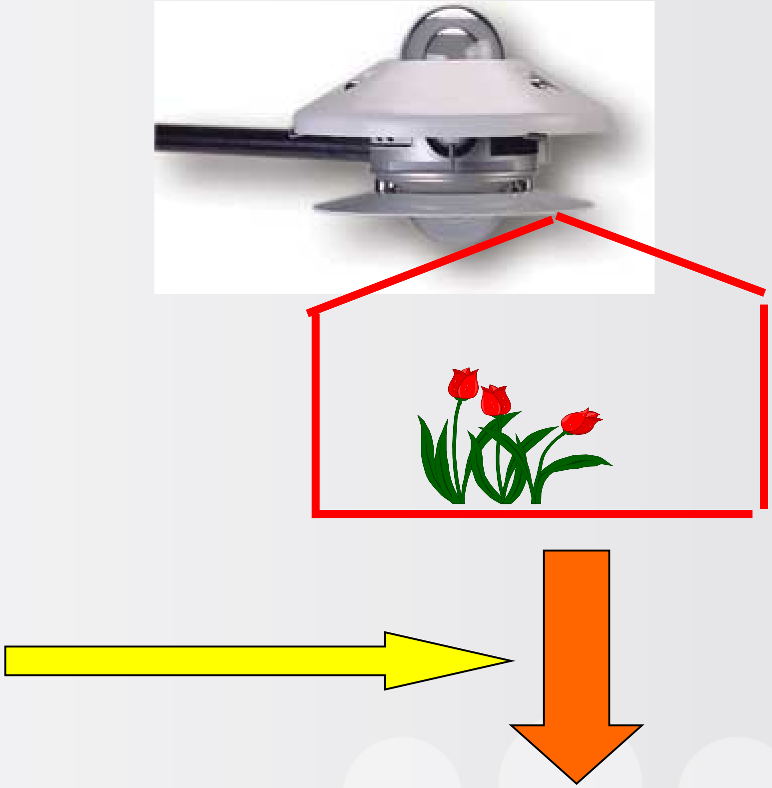


Medrano *et al*. (2008)



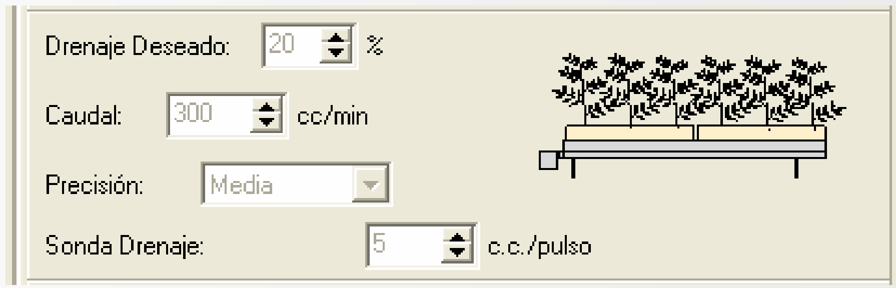
Terés *et al*. (2000)

Automatic irrigation by combining radiation and an automatic drainage tray



Solar radiation sum necessary for irrigation

Automatic irrigation by combining radiation and an automatic drainage tray



Solar time	Irritation number	Drainage (L)	Irrigation (L)	Leaching fraction (LF)	Average LF	Radiation target (Wh m^{-2})
4:13:28	1	0.31	1.5	20%	10.50%	550
10:03:13	2	0.54	1.5	36%	19.00%	550
11:38:43	3	0.11	1.5	7%	16.08%	610
12:26:43	4	0.29	1.5	19%	16.73%	400
13:24:28	5	0.48	1.5	31%	19.22%	400
14:46:58	6	0.51	1.5	34%	21.33%	423

Target of leaching fraction: 20%

Medrano *et al*. (2008)

Irrigation based on a transpiration model (Medrano *et al*., Scientia Horticulturae 105: 163-175)

$$\lambda E = A\, f_1(LAI)\, \tau\, R_g + B\, LAI\, VPD$$

Radiative component: $A\, f_1(LAI)\, \tau\, R_g$

Advective component: $B\, LAI\, VPD$

$$\lambda E = A(1-\exp(-k\, LAI))\, \tau\, R_g + B\, LAI\, VPD$$

λ Latent heat of water vaporization (2440 J g^{-1})

E Crop transpiración (g m^{-2}).

A and B Specific coefficients for each crop

k Radiation extinction coefficient

R_g Outdoors radiation (MJ or Wh)

τ Transmissivity to radiation of greenhouse cover

LAI Leaf area index

VPD Vapour pressure deficit

Crop	A	B day	B night	k
Tomato	0.59	19.1	25	0.64
Cucumber (until 50 days)	0.42	29.1	15	0.86
Cucumber (from 51 days)	0.24	22	15	0.86

Modelisation of LAI

$$LAI = a + \frac{b}{1 + e^{-\left(\frac{DAT-c}{d}\right)}}$$

Medrano (1999)

DAT: Days after transplant

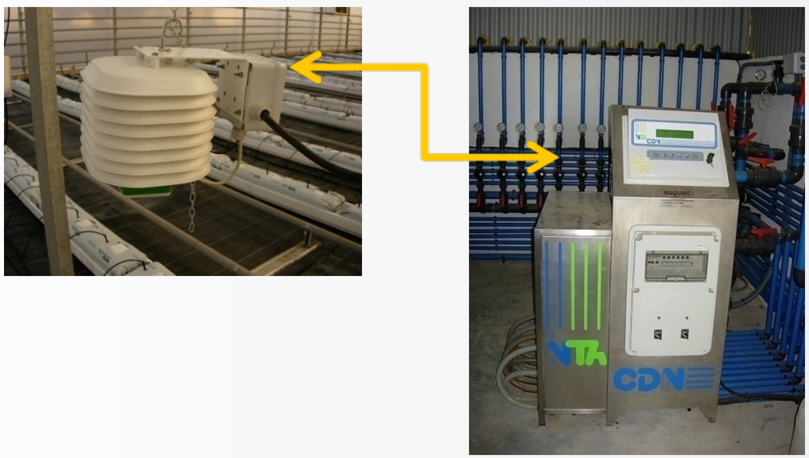
Crop	a	b	c	d
Tomato	-0.46	5.1	43.2	19.1
Cucumber	-	2.7	43.2	8

Medrano *et al*. (2008)

Modelisation of LAI

$$LAI = -a + \frac{b + a}{1 + \exp[\frac{c - CTT}{d}]}$$

Carmassi *et al.* (2007)

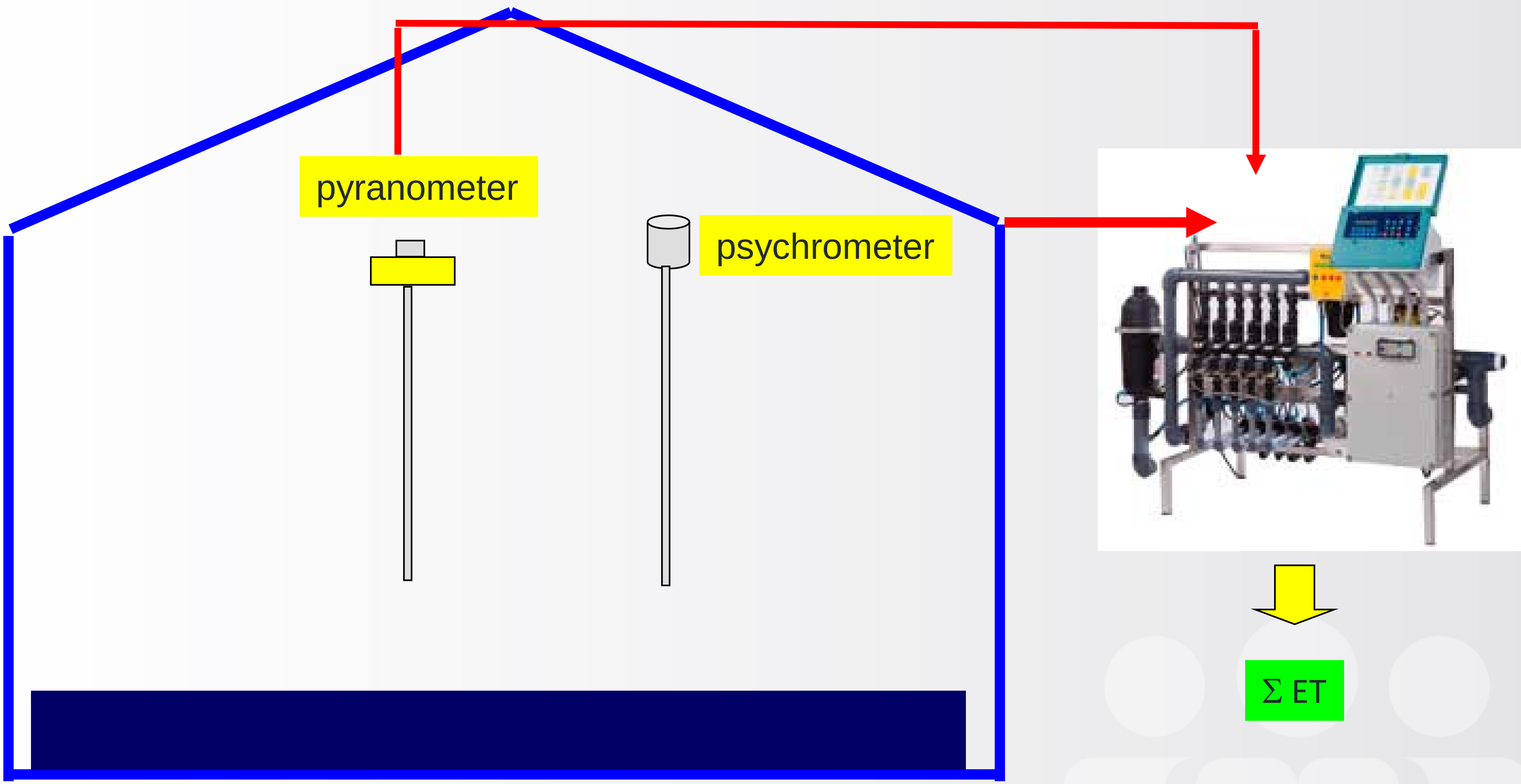


CTT: Cumulative thermal time
Base temperature for tomato: 8ºC

Crop	a	b	c	d
Tomato	0.335	4.803	755.3	134.7

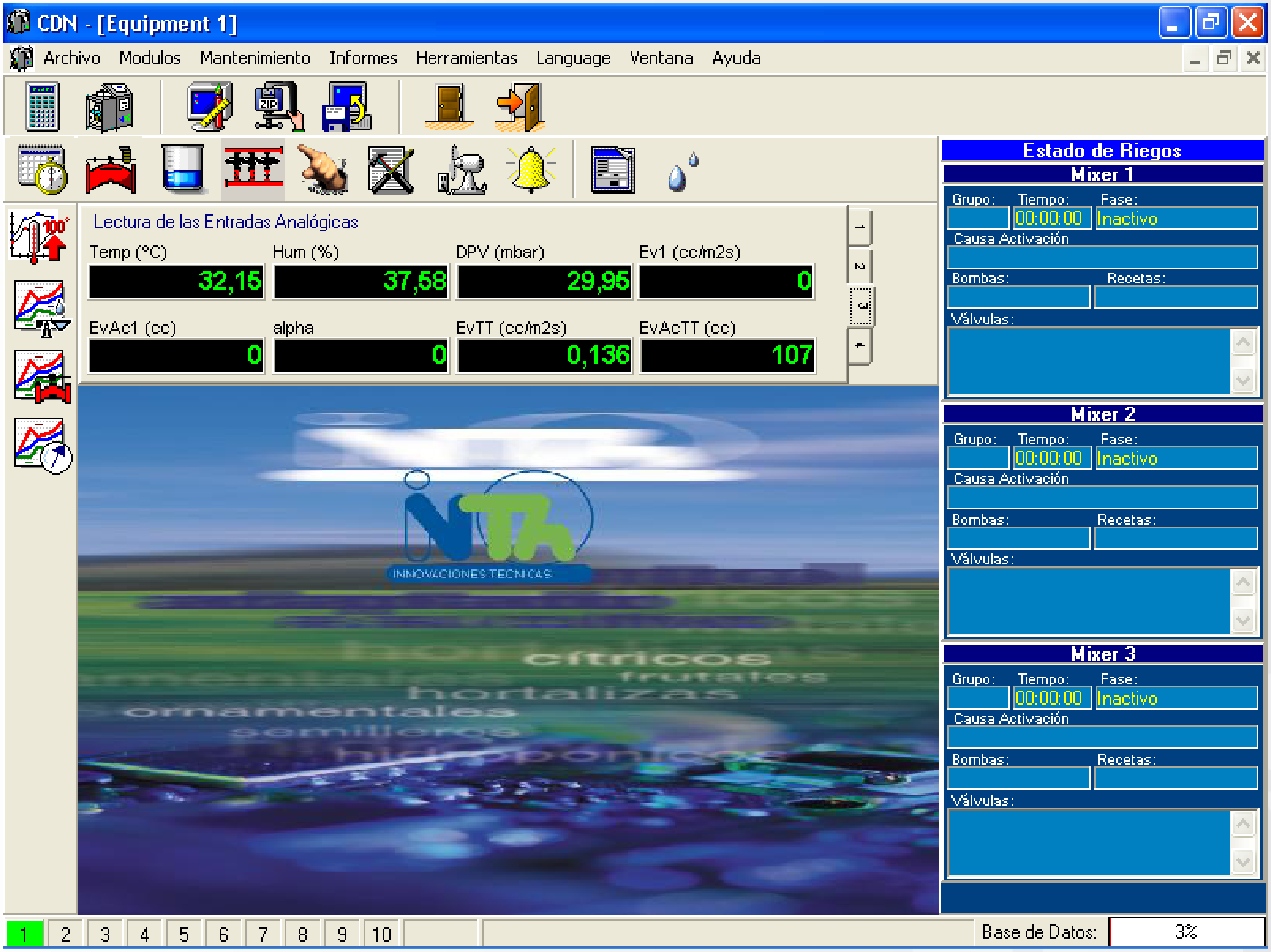
Medrano *et al*. (2008)

Automatic irrigation based on a transpiration model



When Σ ET = target Σ ET $\longrightarrow$ IRRIGATION

Automatic irrigation based on a transpiration model



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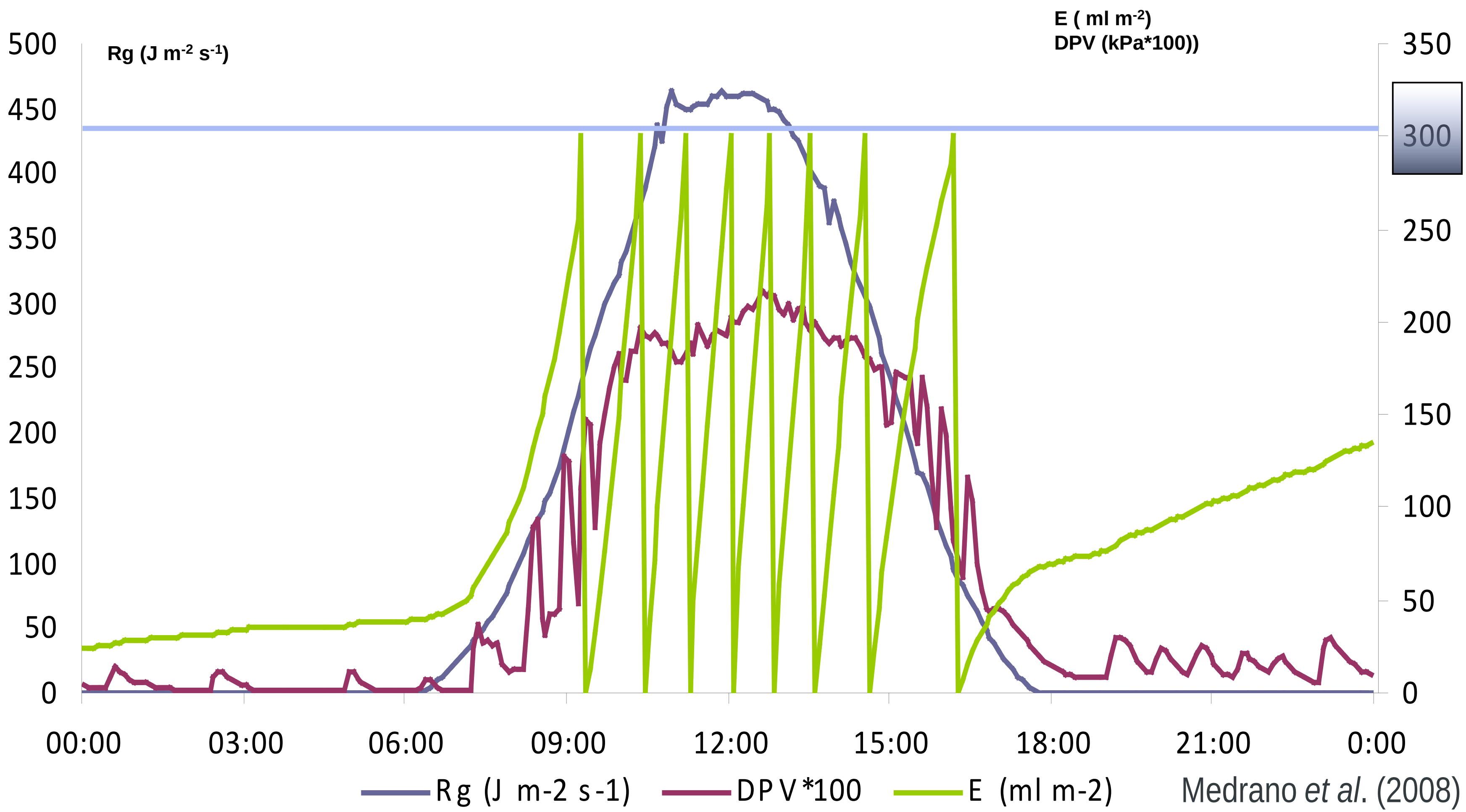
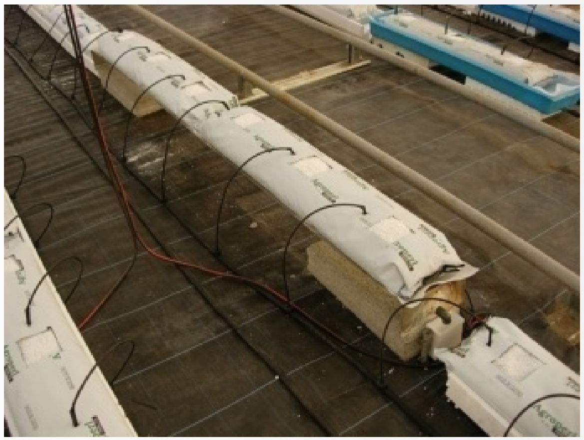
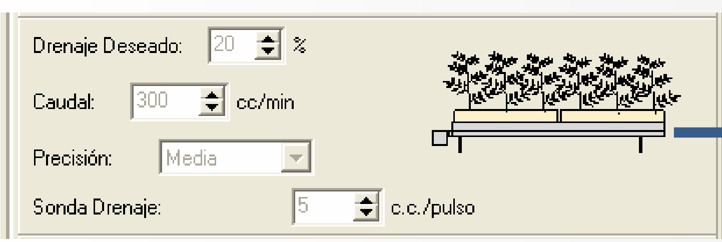


Medrano *et al*. (2008)

Automatic irrigation by combining a transpiration model and an automatic drainage tray





LAI →

$$\lambda E = A\, f_1(LAI)\, \tau\, R_g + B\, LAI\, VPD$$

$$LAI_{Cn} = C_1 \cdot \cdots \cdot C_i \cdot \cdots \cdot C_n \cdot LAI_n$$

$$C_i = -a + b \cdot \left(1 + \left(D_{SP} - D_{DTi} / 100\right)\right)$$

a: 0.5
b: 1.5

Medrano *et al*. (2008)

Experimental comparison between different automatic irrigation control systems

E-DT	E-TT	IR-D	BD
Transpiration model LAI = *f* (DAT)   	Transpiration model LAI = *f* (TT)  	E = *f* (IR)  	 

Experimental comparison between different automatic irrigation control systems

Tomato

***Lycopersicon esculentum* Mill. cv. Boludo**

IFAPA. Almería (Spain)

Cycle: september 4th 2006 to march 25th 2007 (202 days)

Plant density: 2 plants m^{-2}

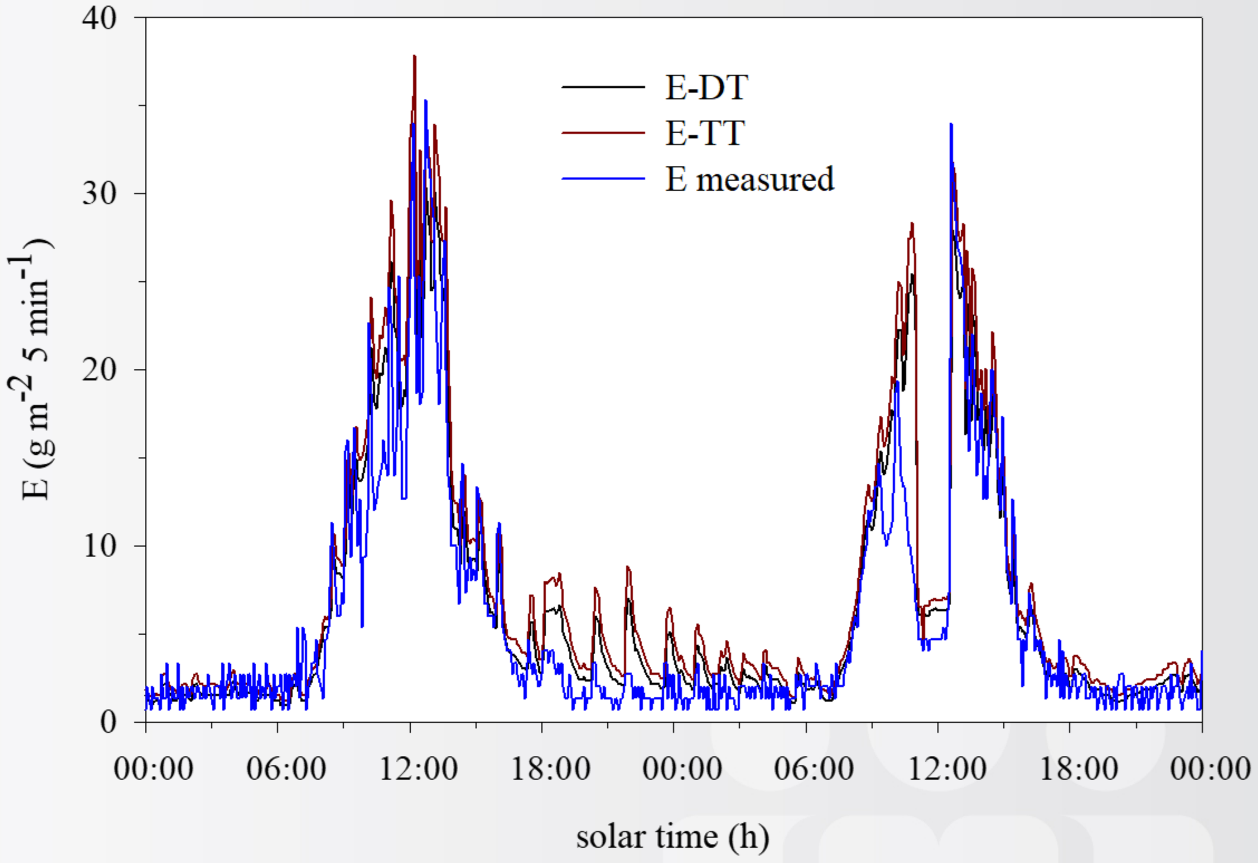
Substrate: 30 L perlite bags

Supplied water: 0.3-0.5 L m^{-2}

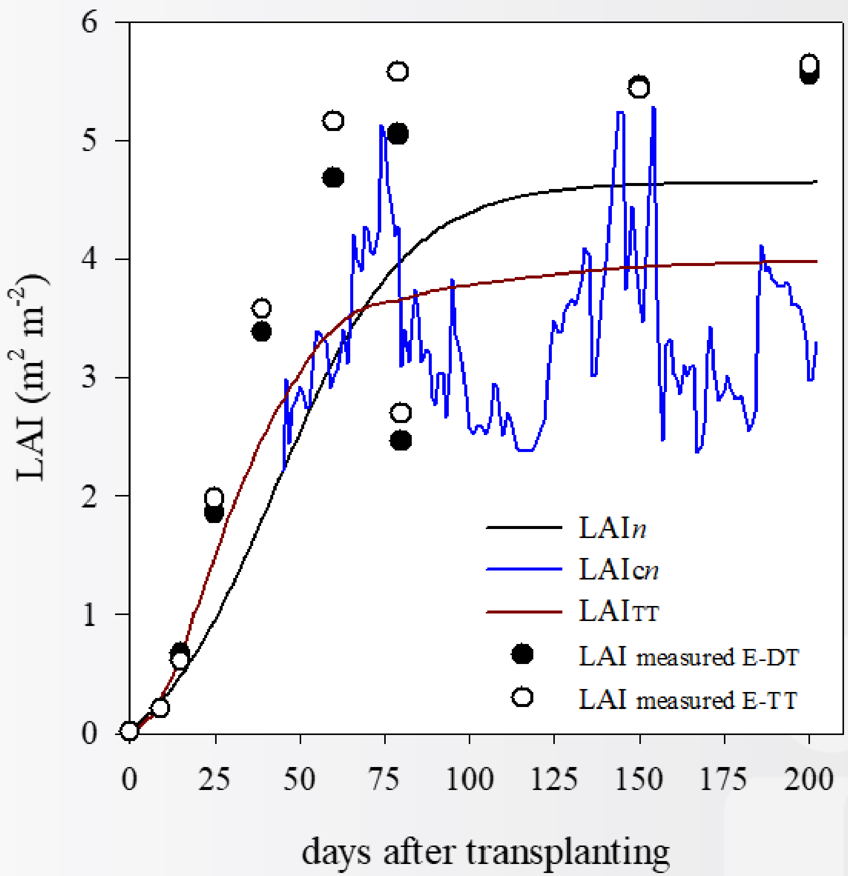
Setpoint drainage: 25%

Integrated pest management

Experimental comparison between different automatic irrigation control systems. Comparison of the measured and calculated transpiration (Medrano *et al*., Acta Horticulturae 801: 1325-1330)



Experimental comparison between different automatic irrigation control systems. LAI estimations (Medrano *et al*., Acta Horticulturae 801: 1325-1330)



Experimental comparison between different automatic irrigation control systems. Yield, water supply and regulations of the systems (Medrano *et al*., Acta Horticulturae 801: 1325-1330)

Treatments	Yield (kg m^{-2})	Water supply (L m^{-2})	Water supply efficiency (g L^{-1})	Regulations of the systems
E-DT	16.7 ab	521.8 a	32.1 a	1
E-TT	17.0 a	524.5 a	32.4 a	6
IR	16.1 b	480.4 c	33.6 a	13
BD	17.4 a	503.1 b	34.6 a	15

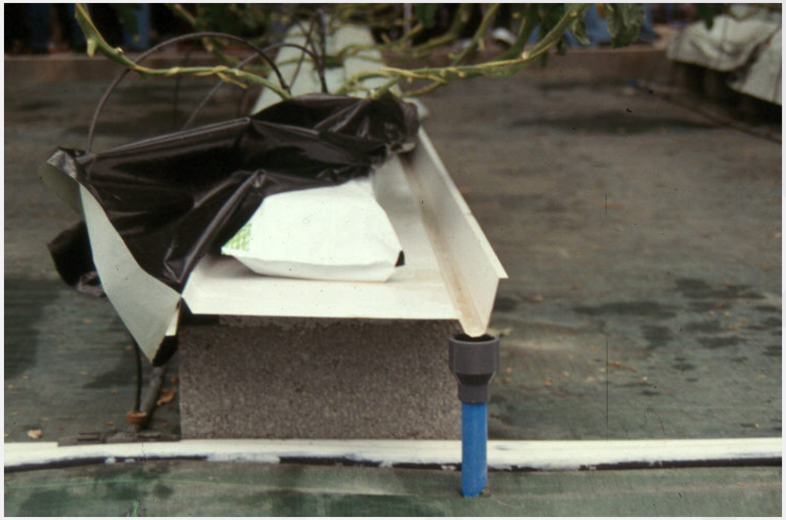
Closed soilless growing systems

Advantages

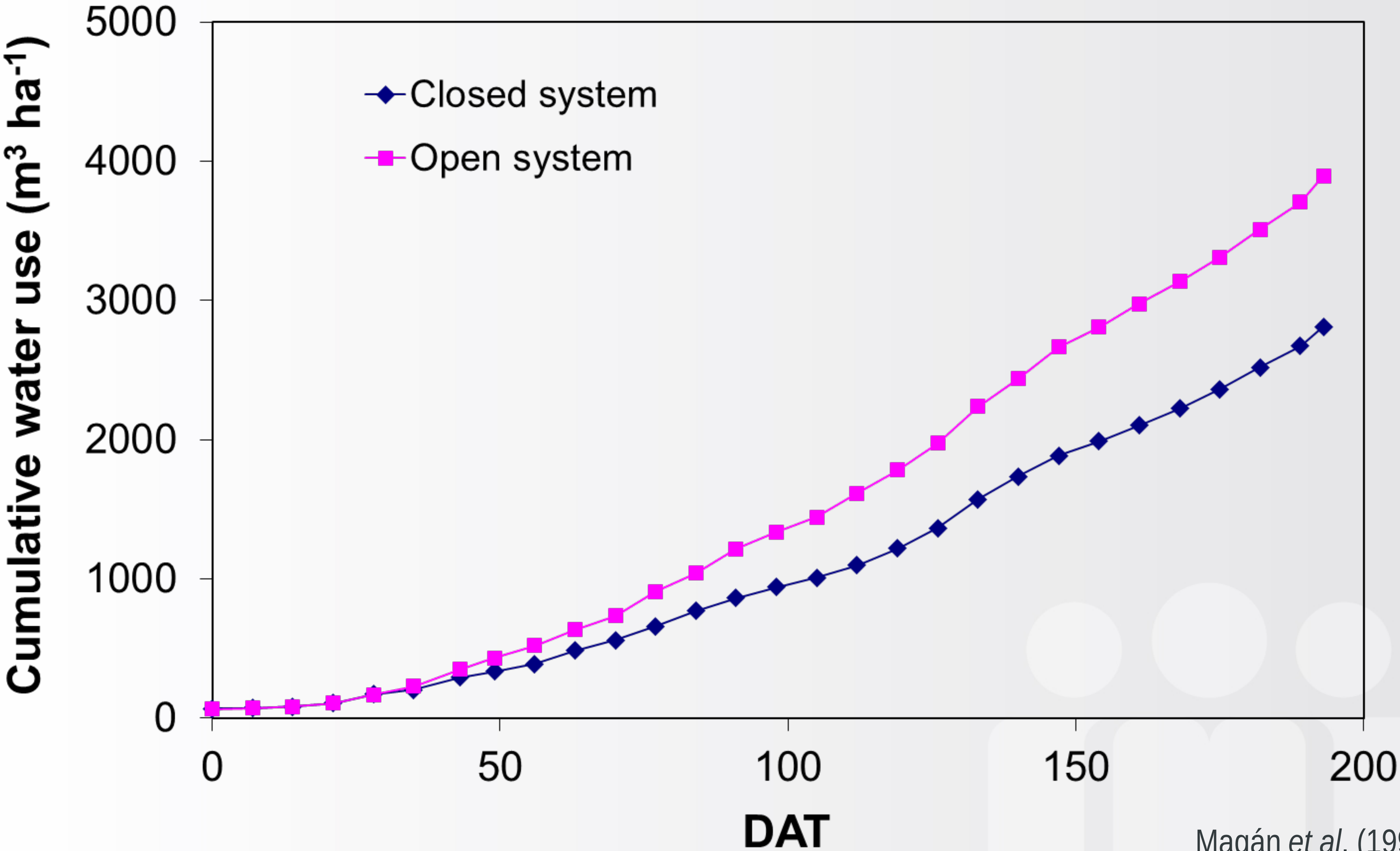
- Significant water and fertilizer savings and reductions of nutrient leaching
- It is posible to establish high leaching fractions and to maintain lower nutrient concentrations

Disadvantages

- Need for extra investment
- Nutritional solution imbalance: need for frequent analysis
- Progressive accumulation of those ions with an excessive concentration in the irrigation water
- Possible dispersal of diseases through the nutrient solution
- Stricter and more experienced follow-up for good results



Evolution of cumulative water use in a tomato crop grown in closed vs. open system

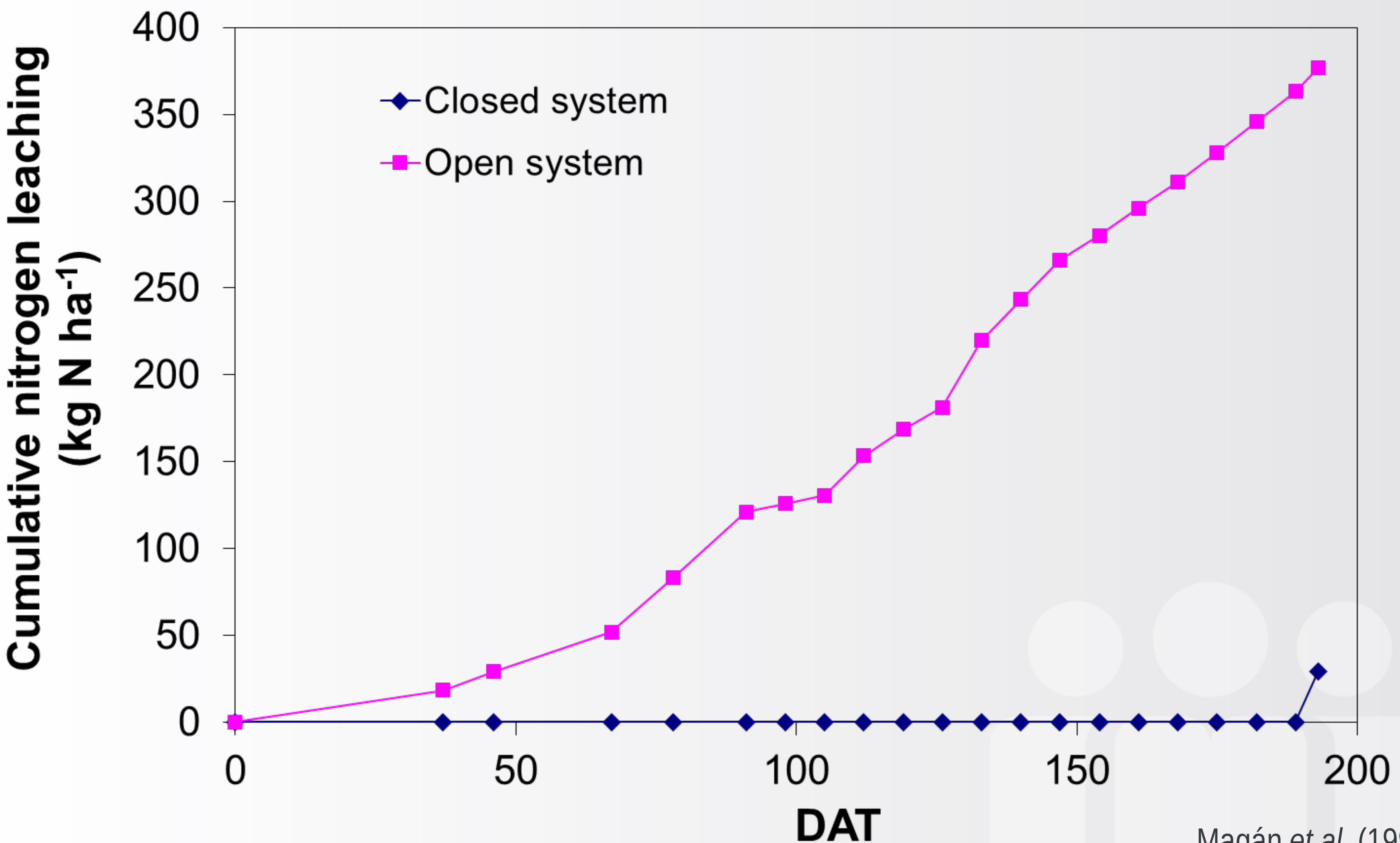


Magán *et al*. (1999)

Fertiliser use in a tomato crop grown in closed vs. open system in the experiment 1

FERTILISER	Use in open system (kg o L ha^{-1})	Use in closed system (kg o L ha^{-1})	Price (€ kg^{-1} o L^{-1})	Expense in open system (€ ha^{-1})	Expense in closed system (€ ha^{-1})	Expense reduction (€ ha^{-1})	Porcentage of reduction (%)
Calcium nitrate	3145.1	1487.6	0.416	1308	619	690	52.7
Ammonium nitrate	54.9	36.6	0.43	24	16	8	33.3
Nitric acid	730.2	614.6	0.3975	290	244	46	15.8
Fosforic acid	94.2	76.2	1.08	102	82	19	19.1
Monopotasium phosfate	707.5	465.5	1.636	1157	762	396	34.2
Potasium nitrate	1249.4	737.2	0.868	1084	640	445	41.0
Potasium sulphate	890.4	583.8	0.66	588	385	202	34.4
Magnesium sulphate	379.4	94.6	0.28	106	26	80	75.1
Microelements	132.0	33.0	8.15	1076	269	807	75.0
Manganese	5.6	15.4	7.81	44	120	-77	-174.5
Iron	0	9.4	14.32	0	135	-135	-
Boron	3.8	5.5	6.30	24	35	-11	-43.3
TOTAL				**5803**	**3333**	**2470**	**42.6**

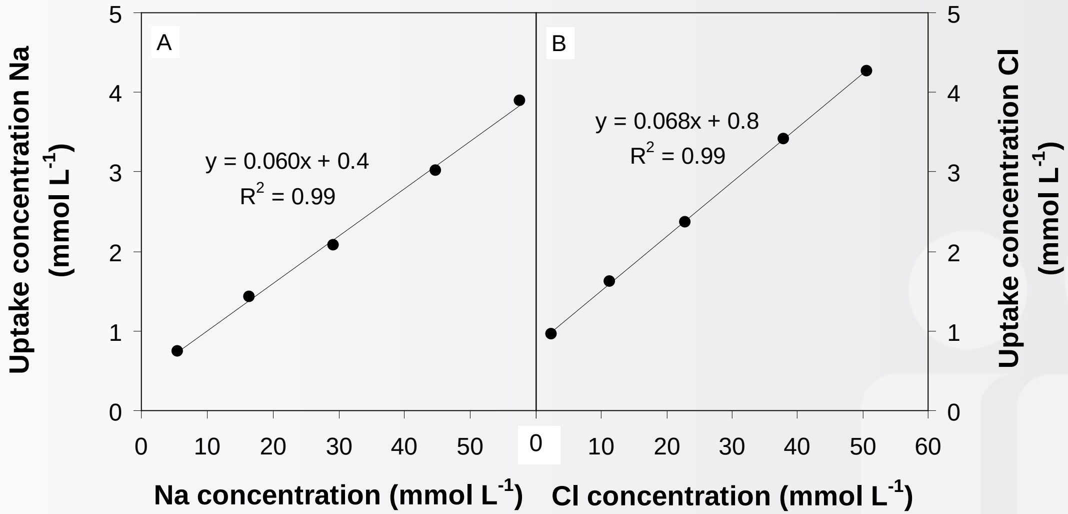
Evolution of cumulative nitrogen leaching in a tomato crop grown in closed vs. open system



Magán *et al*. (1999)

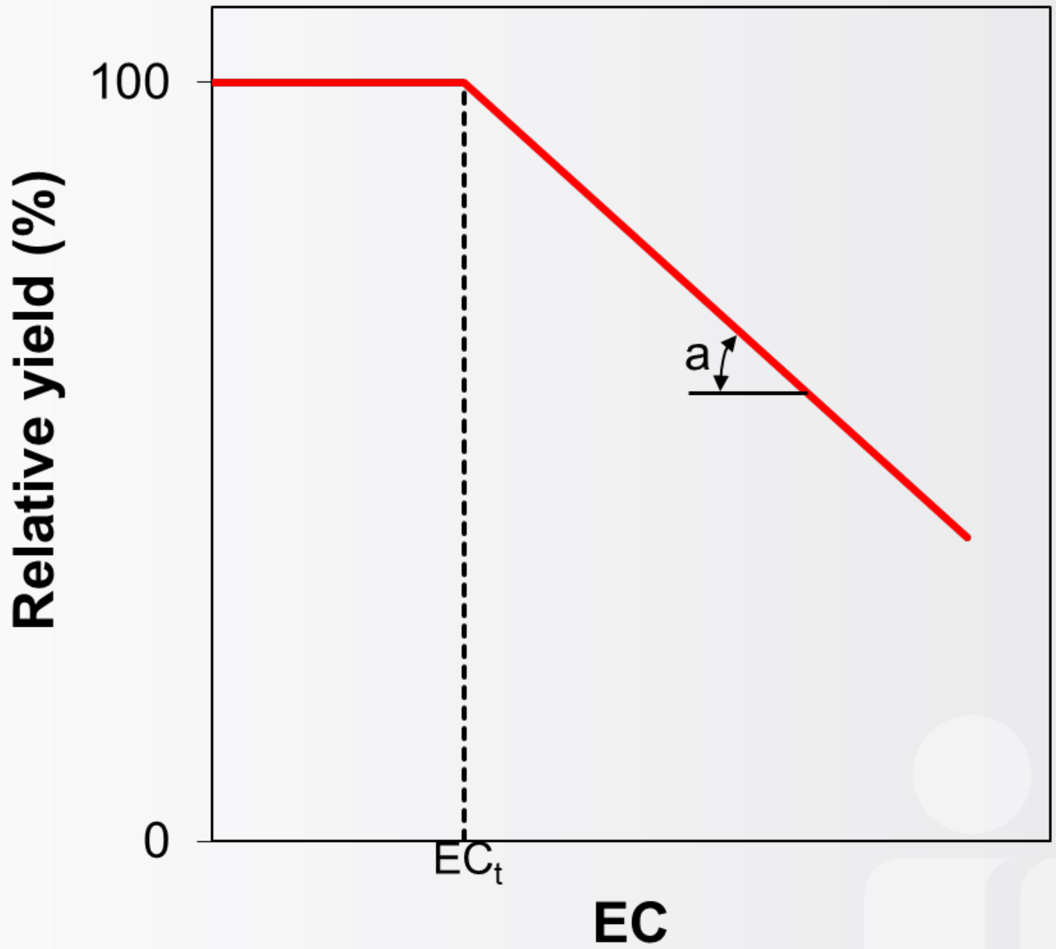
Closed soilless growing systems and salinity

- Poor quality of the irrigation water is one of the most important factors limiting the implementation of closed soilless growing systems in the Mediterranean area.
- An excess of salts in the irrigation water provokes their accumulation in the recirculating solution until a level promoting an uptake concentration equal to the concentration in the water.
- However, an excessive saline accumulation is frequently necessary to achieve this steady state, thereby being compulsory to discharge part of the recirculating solution in order to avoid yield reduction.
- This discharge can promote significant loss of nutrients.



Magán et al. (2005)

Crop response to salinity

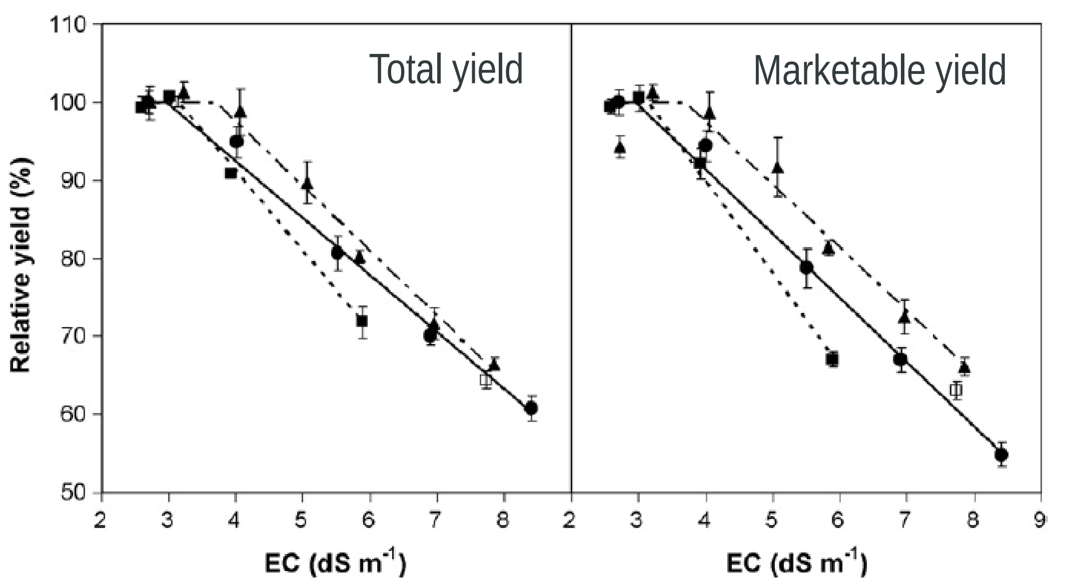


Study of tomato crop response to salinity in SE Spain

3 experiments:

- Experiment 1: Winter to Spring growing cycle cv. ‘Daniela’
- Experiment 2: Winter to Spring growing cycle cv. ‘Boludo’
- Experiment 3: Long growing cycle (late Summer to Spring) cv. ‘Boludo’

Study of crop response to salinity in SE Spain: effect on yield (Magán *et al*., Agricultural Water Management 95: 1041-1055)



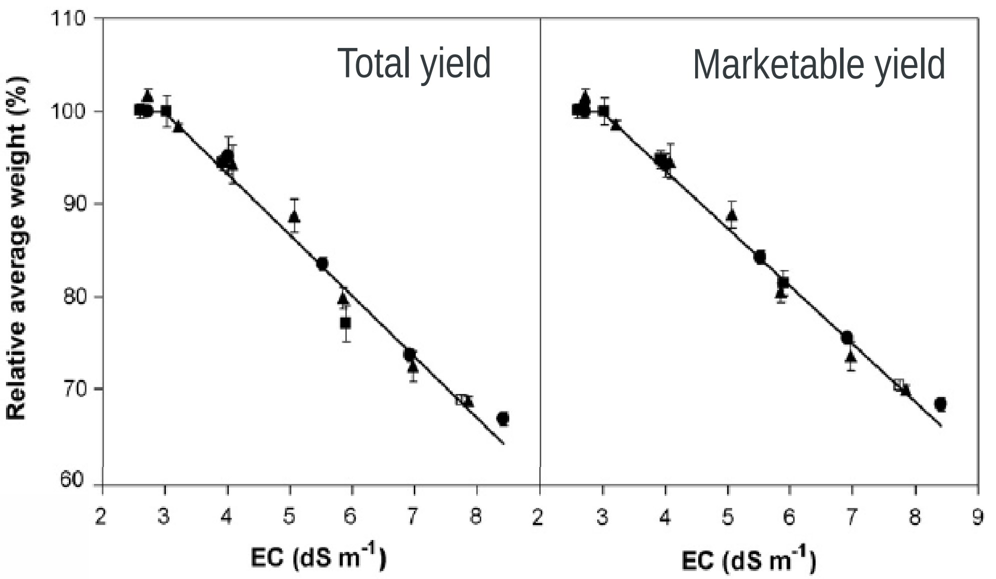
▲ Experiment 1: Spring growing cycle cv. 'Daniela'

■ Experiment 2: Spring growing cycle cv. 'Boludo'

● Experiment 3: Long growing cycle cv. 'Boludo'

	Total fruit yield				Marketable fruit yield		
	EC_t	Slope	r^2		EC_t	Slope	r^2
Experiment 1	3.6	-8.1ab	0.92		3.7	-8.1a	0.90
Experiment 2	3.1	-9.9b	0.96		3.1	-11.8b	0.96
Experiment 3	2.9	-7.2a	0.95		3.0	-8.2a	0.95
		*				**	

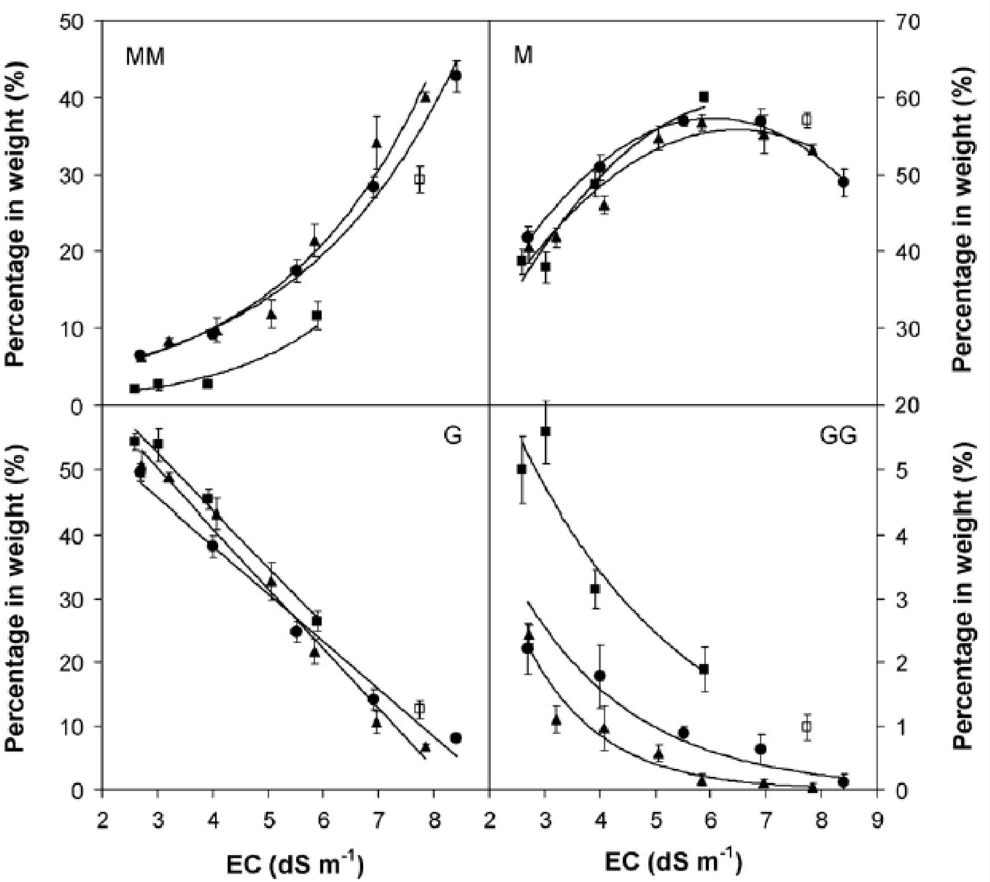
Study of crop response to salinity in SE Spain: effect on average fruit weight (Magán *et al*., Agricultural Water Management 95: 1041-1055)



▲ Experiment 1: Spring growing cycle cv. 'Daniela'
■ Experiment 2: Spring growing cycle cv. 'Boludo'
● Experiment 3: Long growing cycle cv. 'Boludo'

	Average individual fruit weight - total fruit				Average individual fruit weight - marketable fruit		
	EC_t	Slope	r^2		EC_t	Slope	r^2
Experiment 1	3.1	-6.7ab	0.95		3.0	-6.4a	0.96
Experiment 2	3.1	-8.1b	0.92		3.1	-6.5b	0.93
Experiment 3	2.9	-6.2a	0.97		2.8	-5.7a	0.98
		n.s.				n.s.	
Average value		-6.5				-6.1	

Study of crop response to salinity in SE Spain: effect on fruit size (Magán *et al*., Agricultural Water Management 95: 1041-1055)

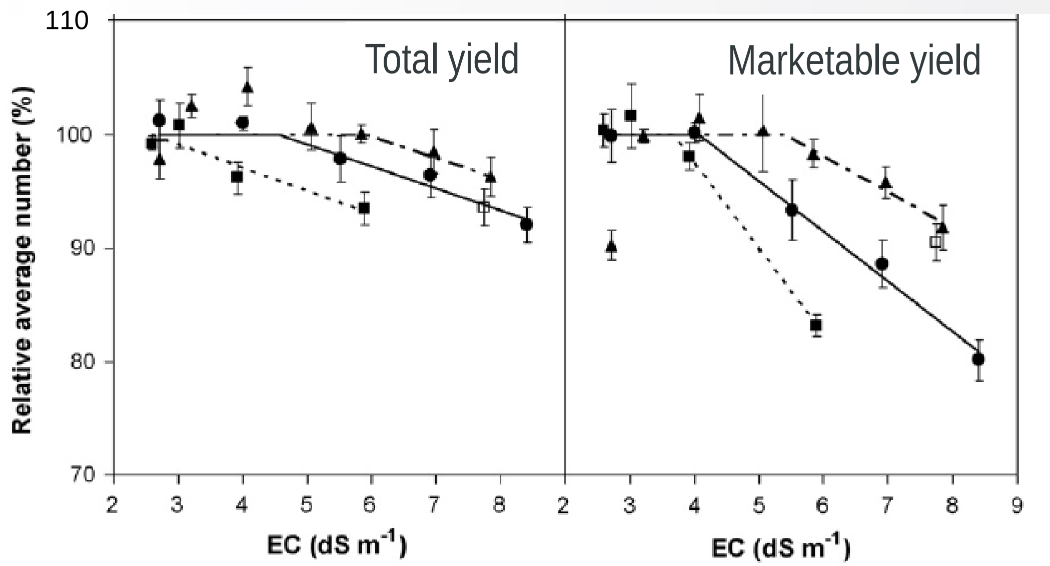


▲ Experiment 1: Spring growing cycle cv. 'Daniela'

■ Experiment 2: Spring growing cycle cv. 'Boludo'

● Experiment 3: Long growing cycle cv. 'Boludo'

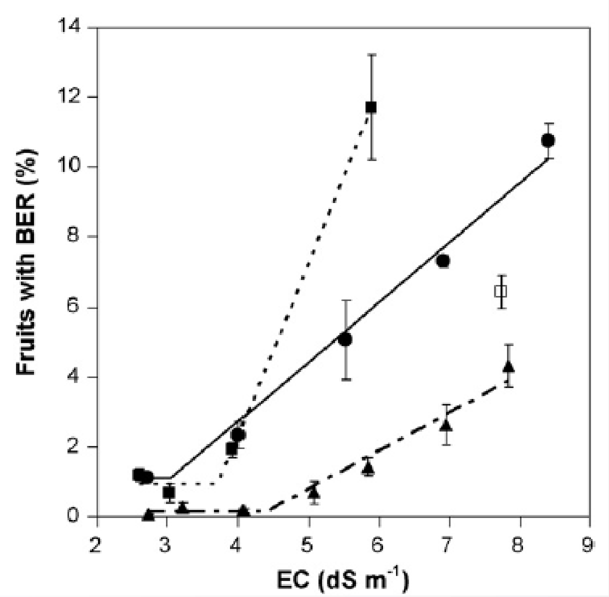
Study of crop response to salinity in SE Spain: effect on fruit number (Magán *et al*., Agricultural Water Management 95: 1041-1055)



▲ Experiment 1: Spring growing cycle cv. 'Daniela'
■ Experiment 2: Spring growing cycle cv. 'Boludo'
● Experiment 3: Long growing cycle cv. 'Boludo'

	fruit number - total fruit				fruit number - marketable fruit		
	EC_t	Slope	r^2		EC_t	Slope	r^2
Experiment 1	5.9	-1.9	0.43		5.4	-3.2a	0.47
Experiment 2	2.6	-2.1	0.47		3.7	-7.6b	0.94
Experiment 3	4.6	-1.9	0.55		4.1	-4.4a	0.81
		n.s.				*	
Average value		-2.0					

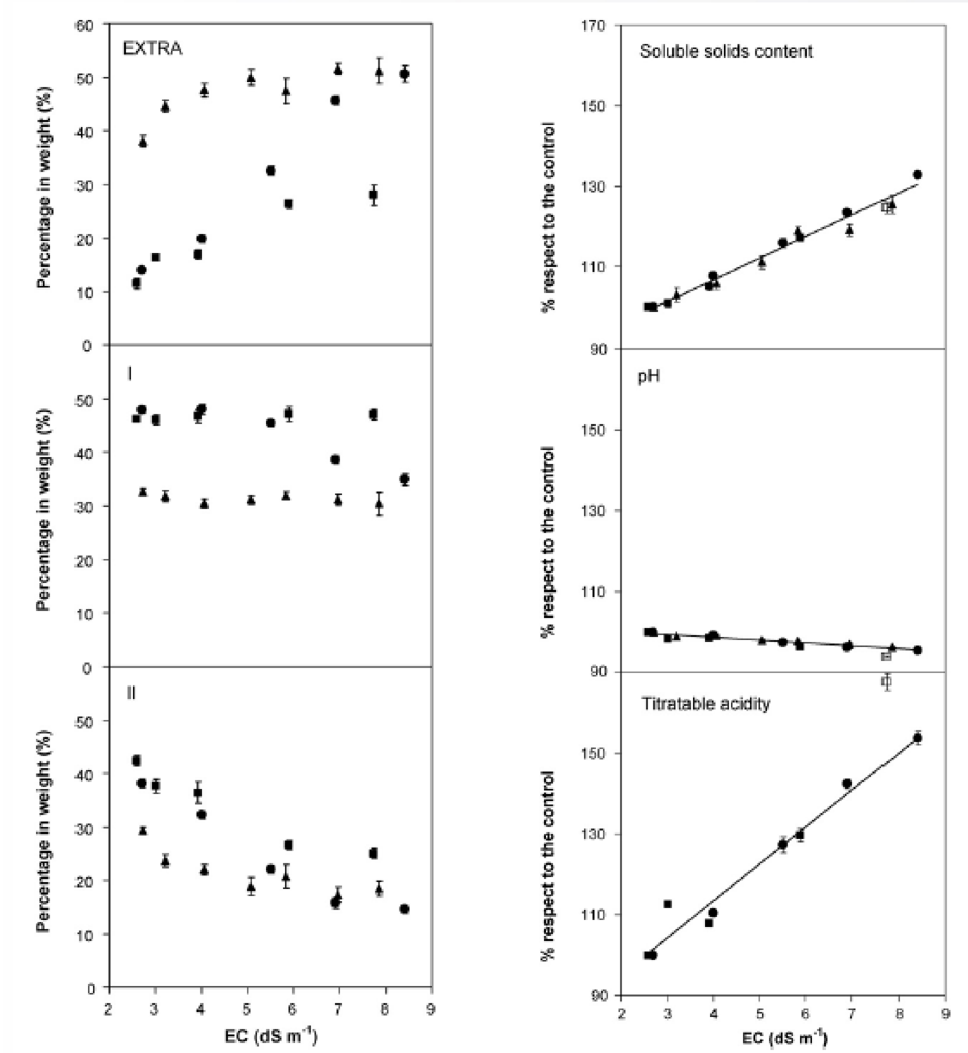
Study of crop response to salinity in SE Spain: effect on BER (Magán *et al*., Agricultural Water Management 95: 1041-1055)



- ▲ Experiment 1: Spring growing cycle cv. 'Daniela'
- ■ Experiment 2: Spring growing cycle cv. 'Boludo'
- ● Experiment 3: Long growing cycle cv. 'Boludo'

	Presence of fruits with BER (% in weight)		
	EC_t	Slope	r^2
Experiment 1	4.78	1.27c	0.97
Experiment 2	3.72	4.97a	
Experiment 3	3.43	1.89b	0.99
		**	

Study of crop response to salinity in SE Spain: effect on external appearance categories and internal quality parameters of fruits (Magán *et al*., Agricultural Water Management 95: 1041-1055)

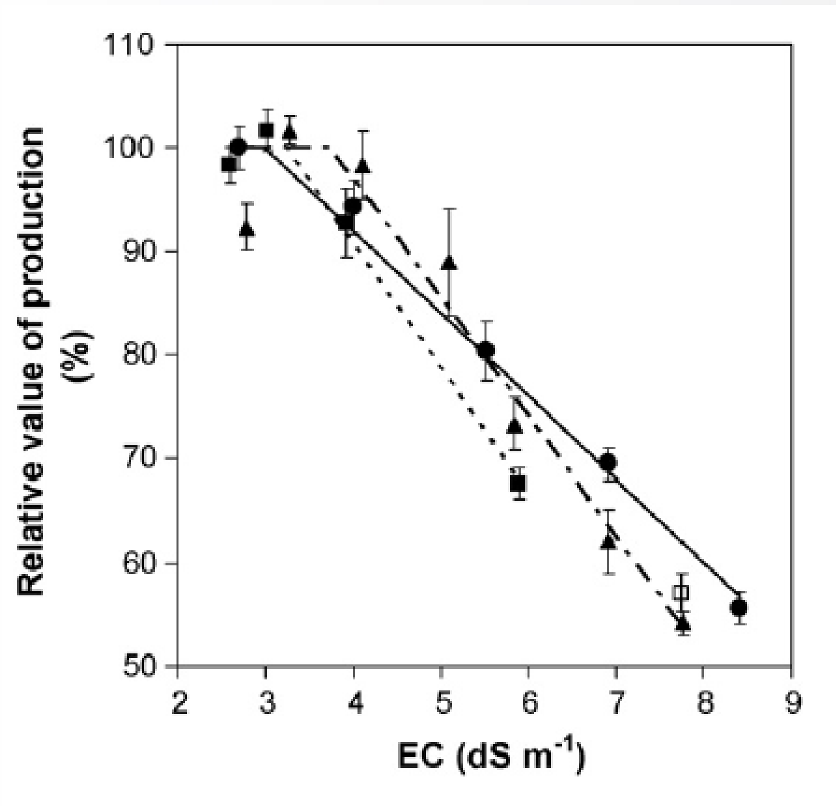


▲ Experiment 1: Spring growing cycle cv. 'Daniela'

■ Experiment 2: Spring growing cycle cv. 'Boludo'

● Experiment 3: Long growing cycle cv. 'Boludo'

Study of crop response to salinity in SE Spain: effect on relative value of production (Magán *et al*., Agricultural Water Management 95: 1041-1055)



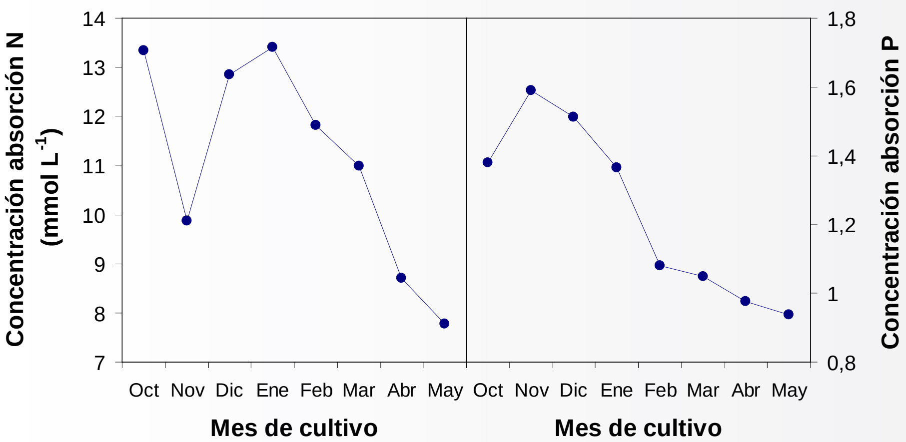
▲ Experiment 1: Spring growing cycle cv. 'Daniela'

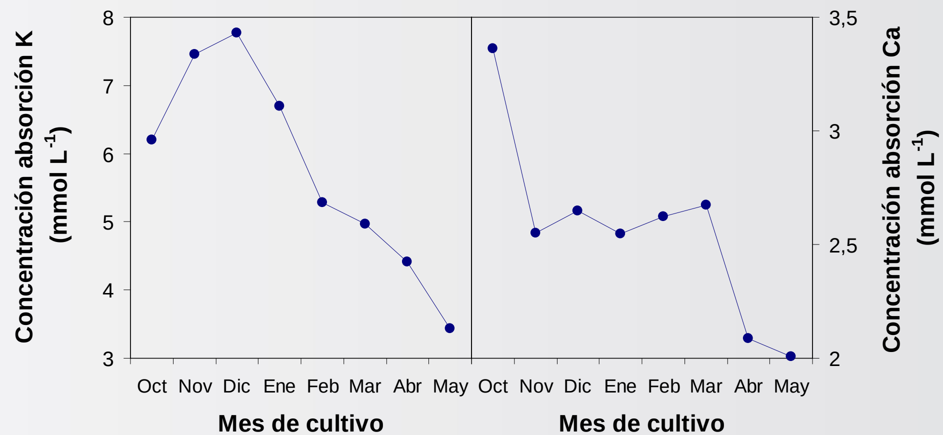
■ Experiment 2: Spring growing cycle cv. 'Boludo'

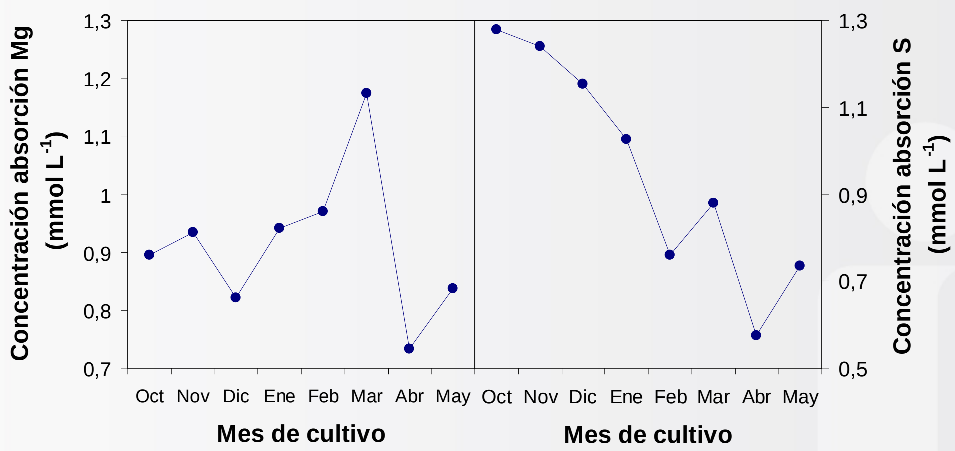
● Experiment 3: Long growing cycle cv. 'Boludo'

Study of crop response to salinity in SE Spain: evolution of the uptake concentration of nutrients in a long tomato growing cycle

To avoid imbalances in the composition of the recirculating nutrient solution, the supply of new nutrients to the system must be equal to the uptake concentrations of the crop. Hence, it is important to have a clear idea about the value of these concentrations.

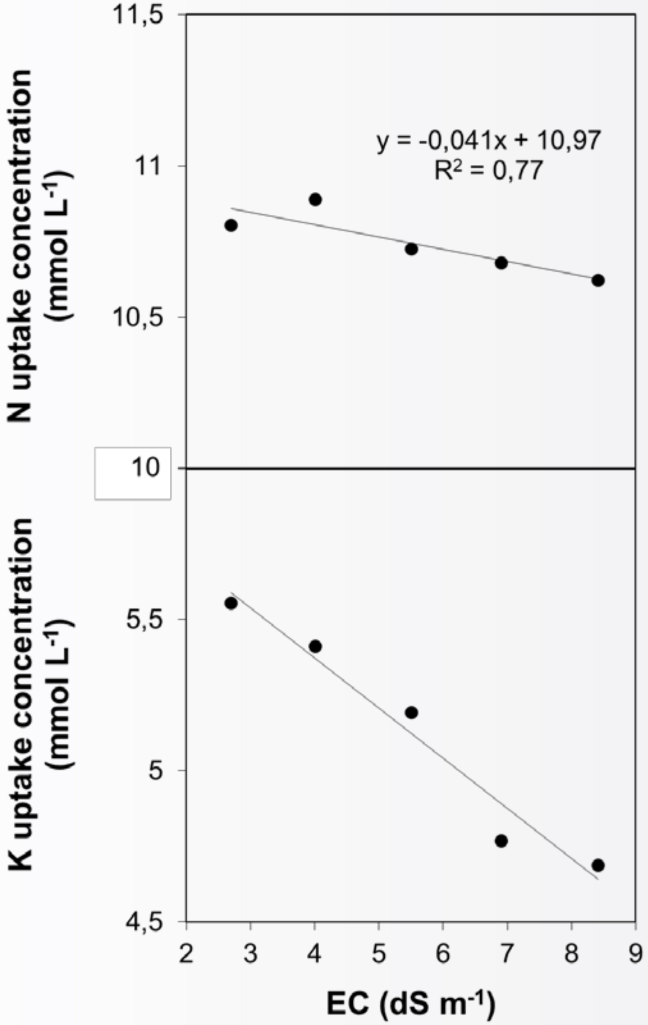


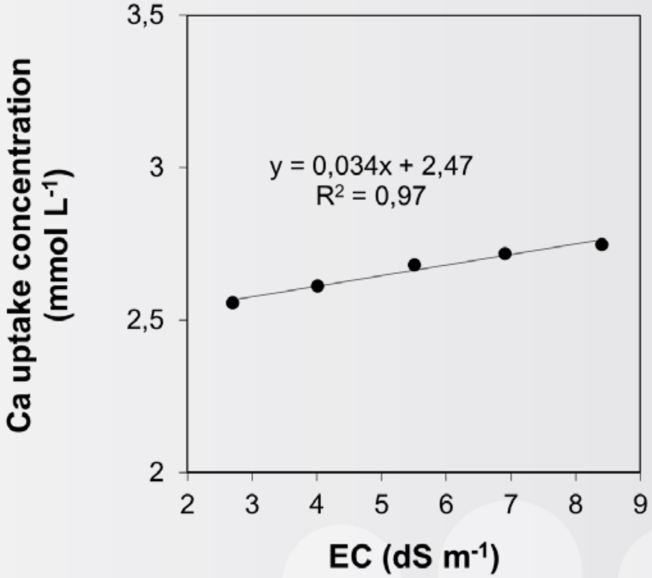




Magán (2005)

Study of crop response to salinity in SE Spain: effect on uptake concentration of nutrients





Magán (2005)

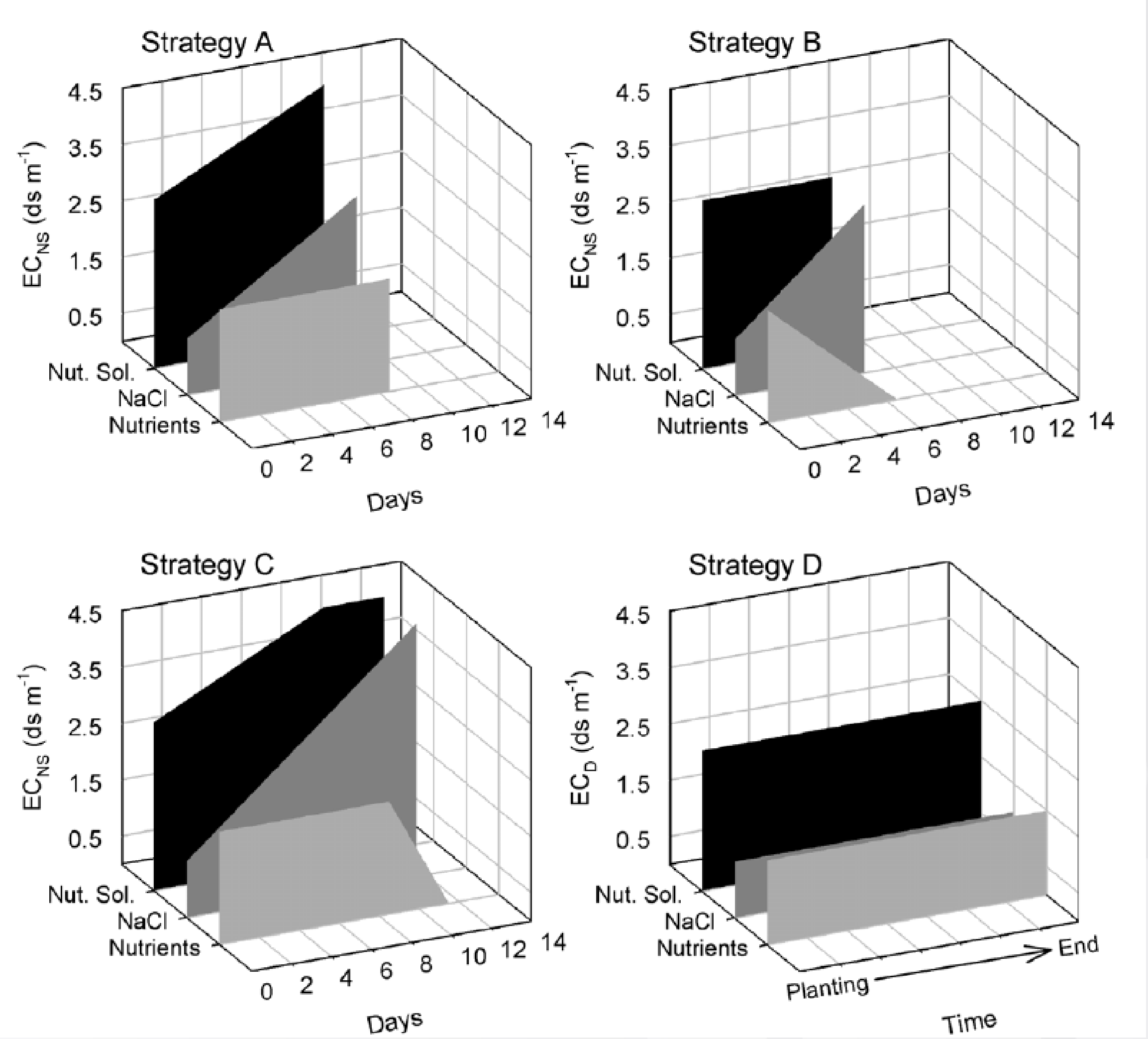
Strategies for readjusting the recirculating solution in closed soilless growing systems

Two strategies can be applied for readjusting the nutrient solution:

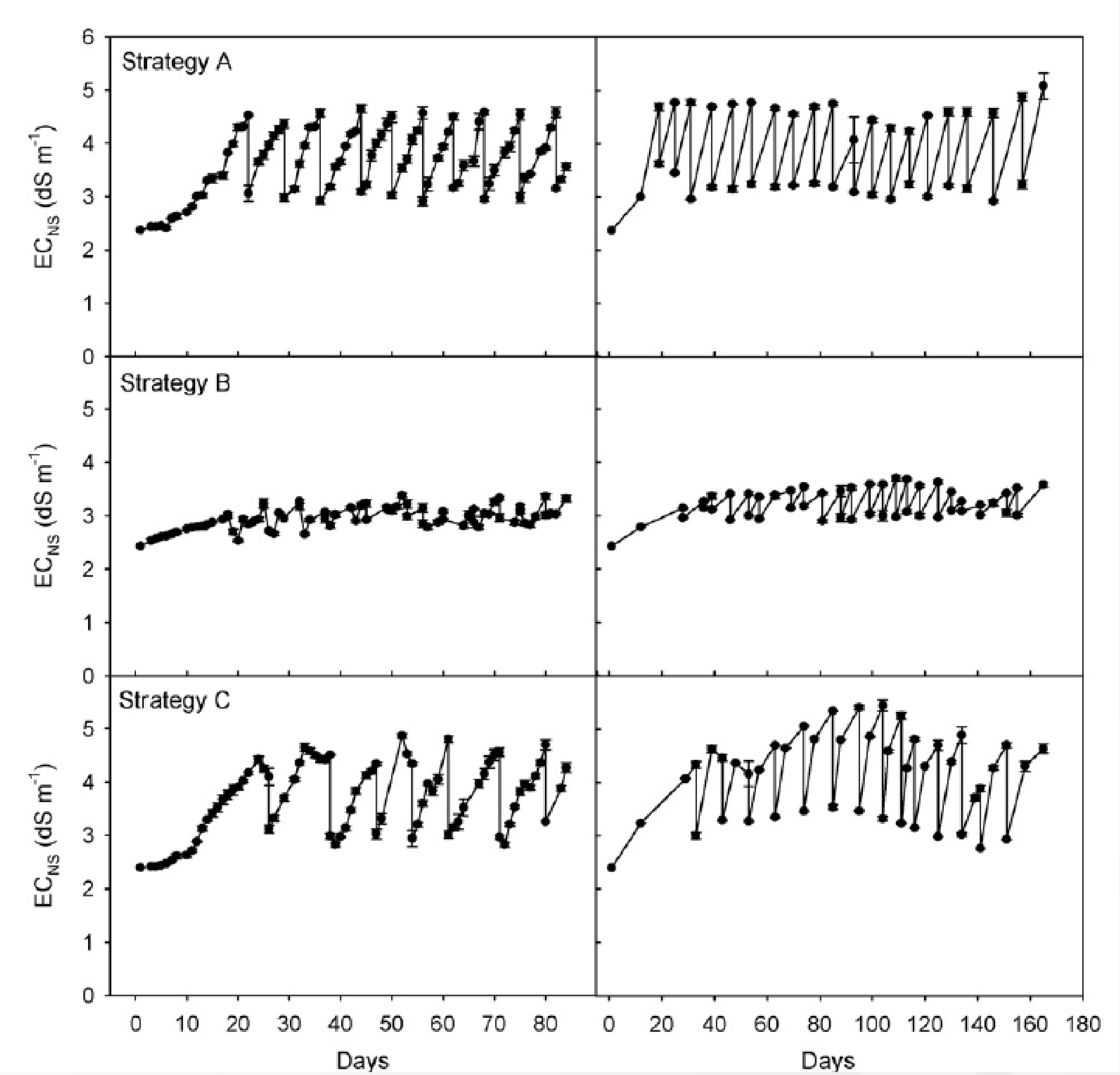
- Mixing drainage with new water and, subsequently, adding nutrients to reach the target EC: this assures to maintain EC but not the presence of nutrients.
- Mixing drainage with new nutrient solution incorporating water and nutrients absorbed by the crop: this assures the presence of nutrients but to not maintain EC.

Comparing strategies for readjusting the recirculating solution using brackish water (Massa *et al*., Agric. Water Manage. 97: 971–980)

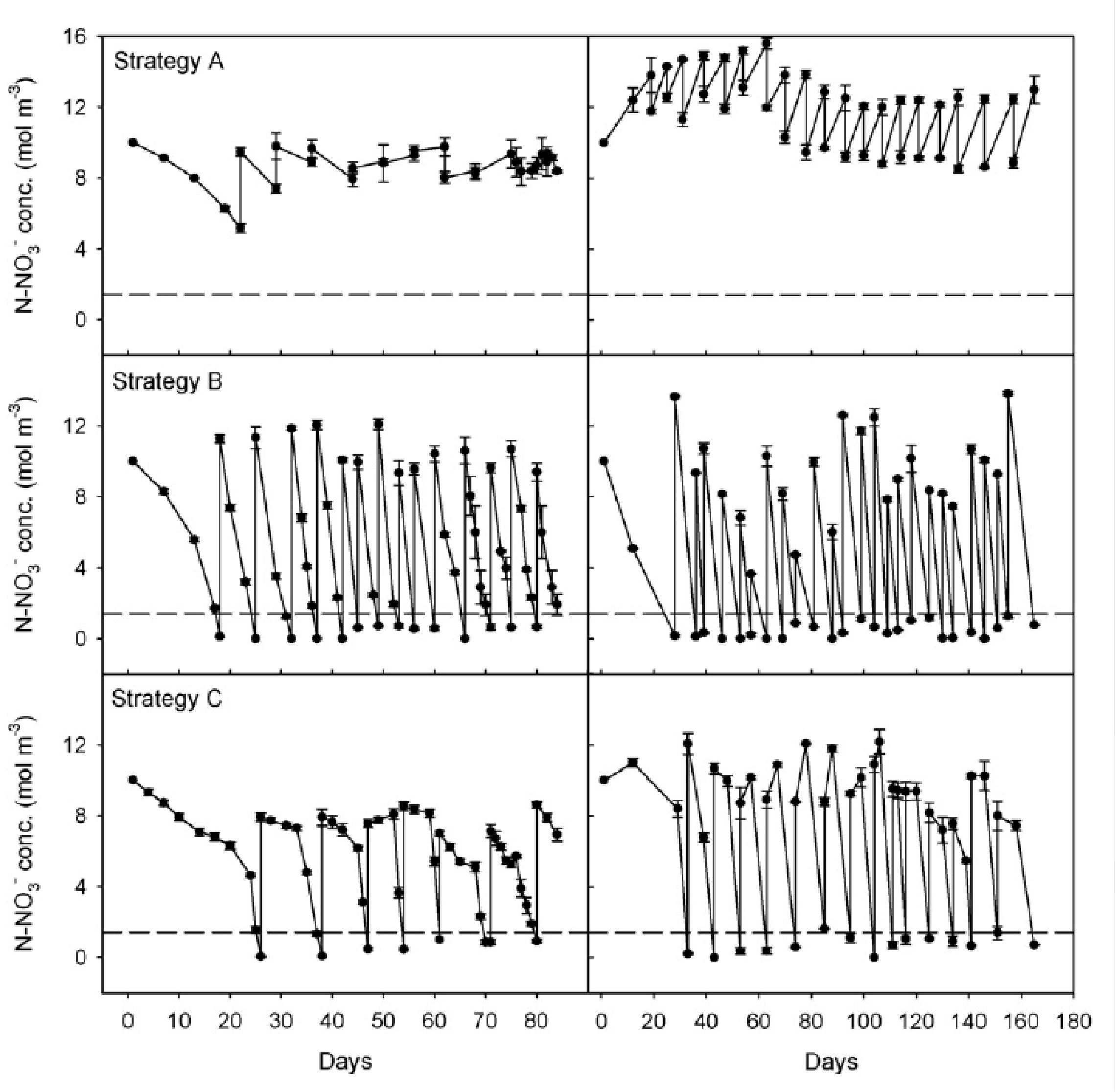
Water quality: 1.5 dS m^{-1} and 9.5 mmol L^{-1} of NaCl



Evolution of EC in the recirculating solution of the different semiclosed treatments (Massa *et al*., Agric. Water Manage. 97: 971–980)



Evolution of N-NO_3^- concentration in the recirculating solution of the different semiclosed treatments (Massa *et al*., Agric. Water Manage. 97: 971–980)



Effect of the recirculation strategy on the water and nitrogen balance in the different treatments (Massa *et al*., Agric. Water Manage. 97: 971–980)

	Estrategy A	Estrategy B	Estrategy C	Estrategy D
Experiment 2005				
Water uptake (m^3 ha^{-1})	3517 b	3428 b	3586 ab	3643 a
Water loss (m^3 ha^{-1})	1960 b	2680 c	1420 d	7198 a
Water use (m^3 ha^{-1})	5477 c	6108 b	5006 d	10841 a
N uptake (kg ha^{-1})	432 b	384 c	455 b	500 a
N leaching (kg ha^{-1})	168 b	14 c	22 c	715 a
N use (kg ha^{-1})	600 b	398 d	477 c	1215 b
Experiment 2006				
Water uptake (m^3 ha^{-1})	6470 a	6524 a	6482 a	
Water loss (m^3 ha^{-1})	3200 b	4000 a	2400 c	
Water use (m^3 ha^{-1})	9670 b	10524 a	8882 c	
N uptake (kg ha^{-1})	879 a	564 c	660 b	
N leaching (kg ha^{-1})	371 a	23 b	24 b	
N use (kg ha^{-1})	1250 a	587 c	684 b	

Validation of Massa *et al*. (2010)'s strategy

- Growing system: NGS
- Crop: tomato 'Valkirias' grafted on 'Multifort', from 16 September 2014 to 25 May 2015, 1.56 plants m^{-2} with two stems per plant (one every three stems was topped on 17 November)

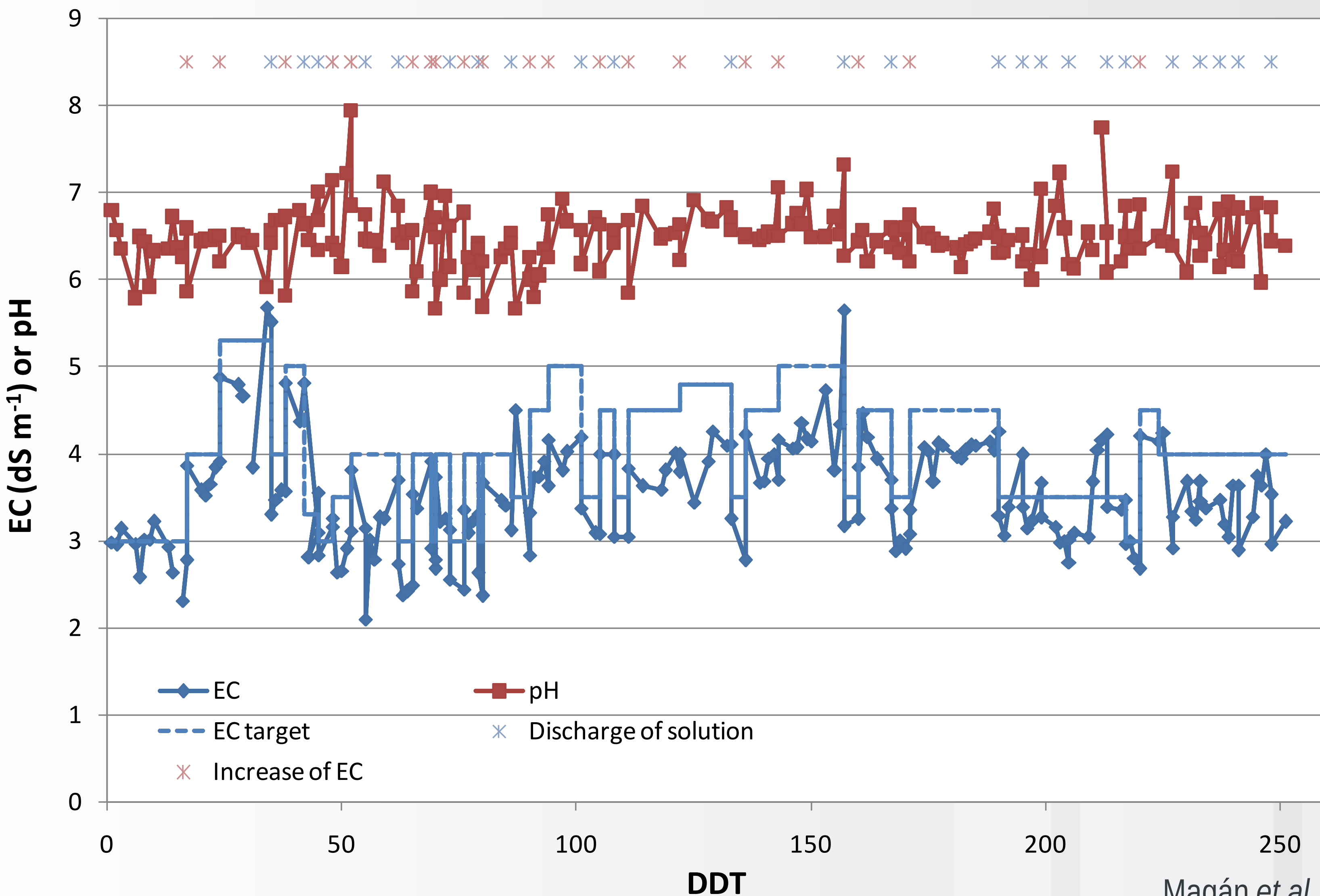
Validation of Massa *et al*. (2010)'s strategy

- Irrigation water used in the experiment: EC = 1.6 dS m^{-1}

ION	NO_3^-	$H2PO_4^-$	$SO_4^=$	HCO_3^-	Cl^-	K^+	Ca^{++}	Mg^{++}	Na^+
Concentration (mM L^{-1})	0.2	0	0.4	3.0	12.3	0.1	2.2	2.9	5.9

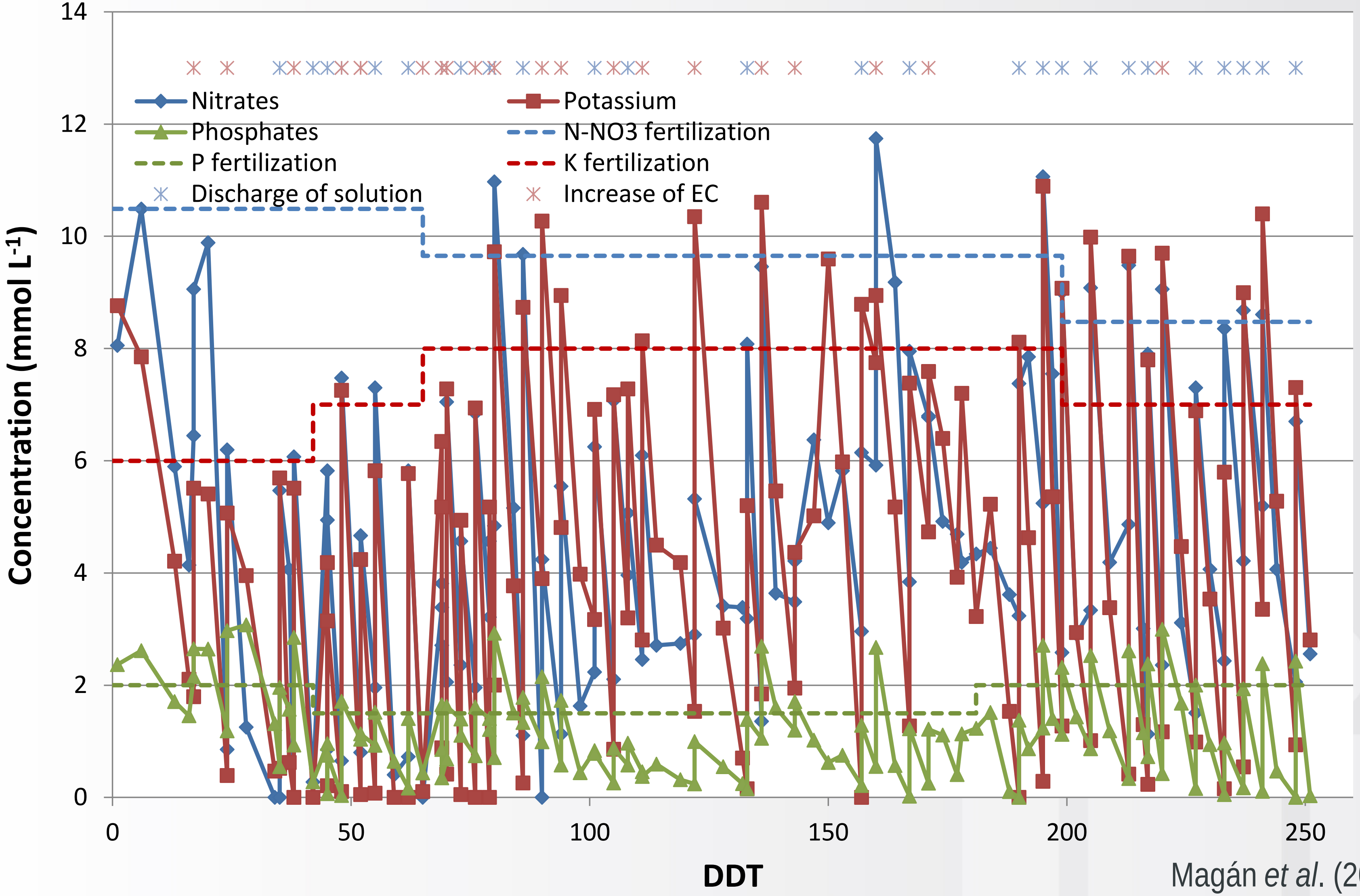
- Daily measurement of nitrates and potassium concentration by using rapid selective electrodes (LaquaTwin, Horiba). An EC of 3 dS m^{-1} was established when starting with new recirculating solution; that target was increased to 4 dS m^{-1} when the concentration of one of the two ions reached a value by 15 ppm. The recirculating solution was discharged when the nutrient concentration decreased again.

Evolution of EC in the recirculating solution



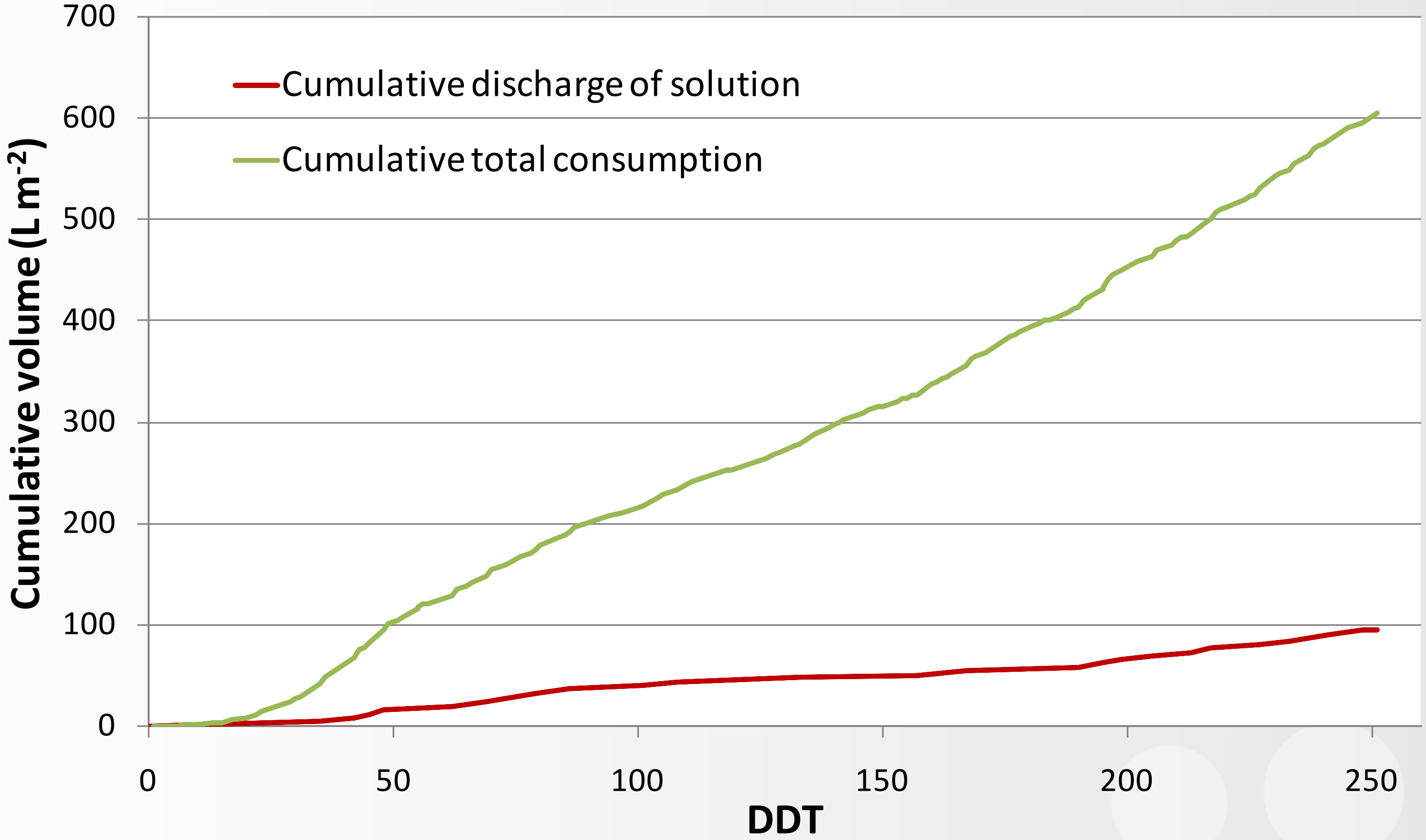
Magán *et al.* (2017)

Evolution of nitrates, phosphates and potassium concentration in the recirculating solution



Magán *et al.* (2017)

Evolution of cumulative water use



Total water use: 605 L m^{-2}

Discharged solution: 95 L m^{-2} (15.6%)

Water use efficiency: 37.5 g L^{-1}

Magán *et al*. (2017)

Supply of macronutrients and use efficiency

NUTRIENT	N	P_2O_5	K_2O
Total supply of macronutrients (UF ha^{-1})	764	426	1194
Ratio between macronutrients (in relation to N)	1.00	0.56	1.56
Discharge of nutrients (%)	4.4	7.8	2.7
NUTRIENT USE EFFICIENCY (kg UF^{-1})	297	533	190
Efficiency in Magán *et al*. (1999) with recirculation (kg UF^{-1})	276	400	154
Efficiency in Magán *et al*. (1999) without recirculation (kg UF^{-1})	156	278	98
Efficiency in Magán *et al*. (2001) with recirculation good water (kg UF^{-1})	304	404	174
Efficiency in Magán *et al*. (2001) with recirculation non-optimal quality water (kg UF^{-1})	248	373	152

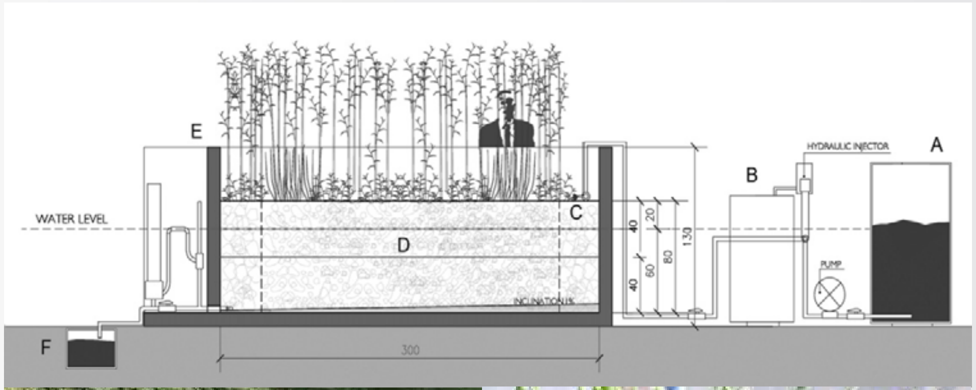
The strategy applied for the management of the nutrient solution allows an excelent water and nutrient use to be achieved without loosing yield when non-optimal quality water is used in recirculation, although it requires the daily measurement of the nutrient concentration. The development of technology enabling automatic measurements will facilitate the adoption of that strategy by growers.

Magán *et al*. (2017)

Evaluation of CLEANLEACH system to recover and purify leachates of agricultural origin by artificial lagoon (www. cleanleach.eu)

Denitrification process

$$1.25\ CH_3COOH + 2NO_3^- = 2.5\ CO_2 + N_2 + 2OH^- + 1.5\ H_2O$$



Denitrifier plants
- Iris pseudoacorus
- Scirpus
- Vetiver

Desalination plants
- Salicornia
- Salcocornia

Evaluation of CLEANLEACH system to recover and purify leachates of agricultural origin by artificial lagoon

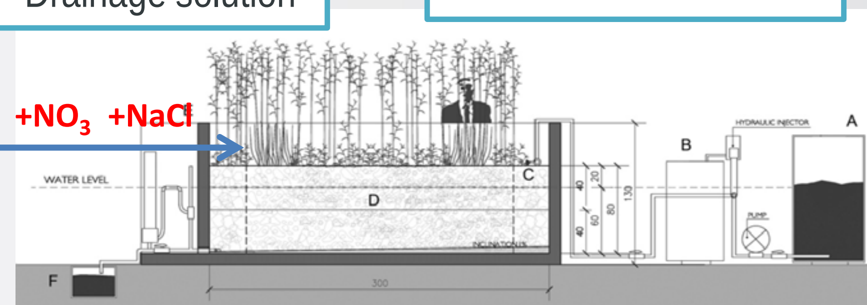
The CLEANLEACH solution consists of a system for recovering and treating leachates based on constructed wetlands

Collecting Tanks

Drainage solution

Constructed wetland

$+NO_3$ $+NaCl$



Denitrification plants
- Iris pseudoacorus
- Cyperus
- Vetiver

Desalination plants
- Salicornia
- Salcocornia

$-NO_3$ $+NaCl$

Water effluent

To the crop
To another crop

$+NO_3$
$-NaCl$

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Instituto de Investigación y Formación Agraria y Pesquera
cajamar
CAJA RURAL

Evaluation of CLEANLEACH system to recover and purify leachates of agricultural origin by artificial lagoon

Before

After

Planting date: 30 october 2017

1 x 2 x 1 m

High density poliethilene

8-12 mm ϕ silica grava

Evaluation of CLEANLEACH system to recover and purify leachates of agricultural origin by artificial lagoon

Denitrification process

$$1.25\ CH_3COOH + 2NO_3^- = 2.5\ CO_2 + N_2 + 2OH^- + 1.5\ H_2O$$

Electric carbon injector

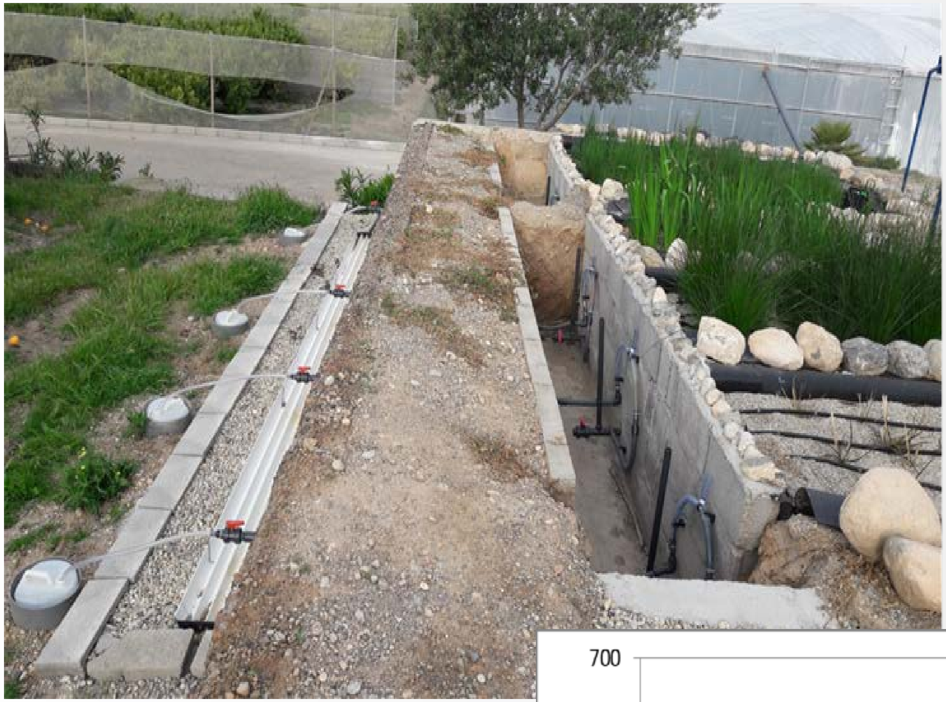
Sodium acetate tank as a carbon source

Tank with drainage solution to be purified

October 2017

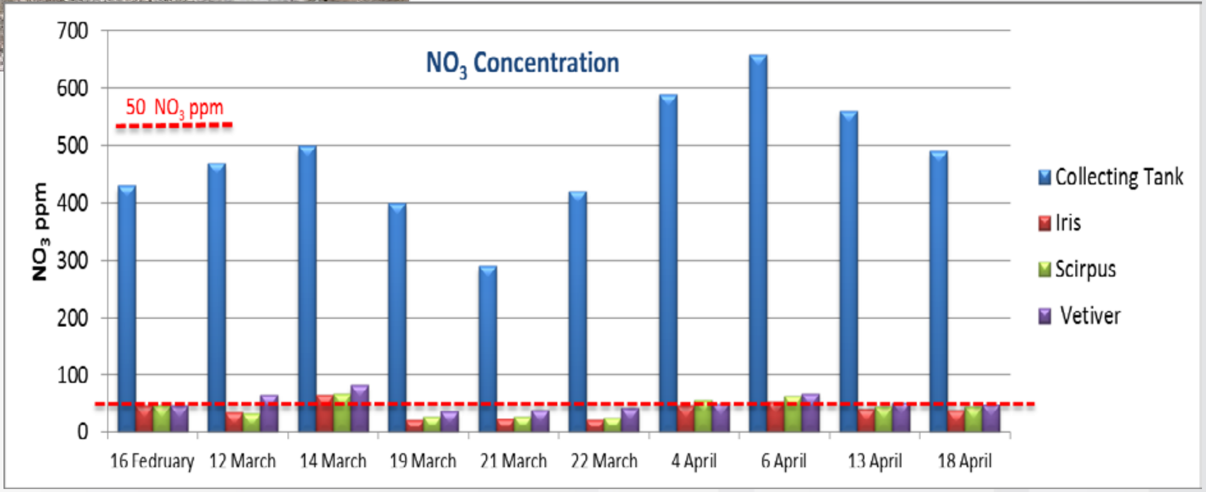
August 2018

Evaluation of CLEANLEACH system to recover and purify leachates of agricultural origin by artificial lagoon

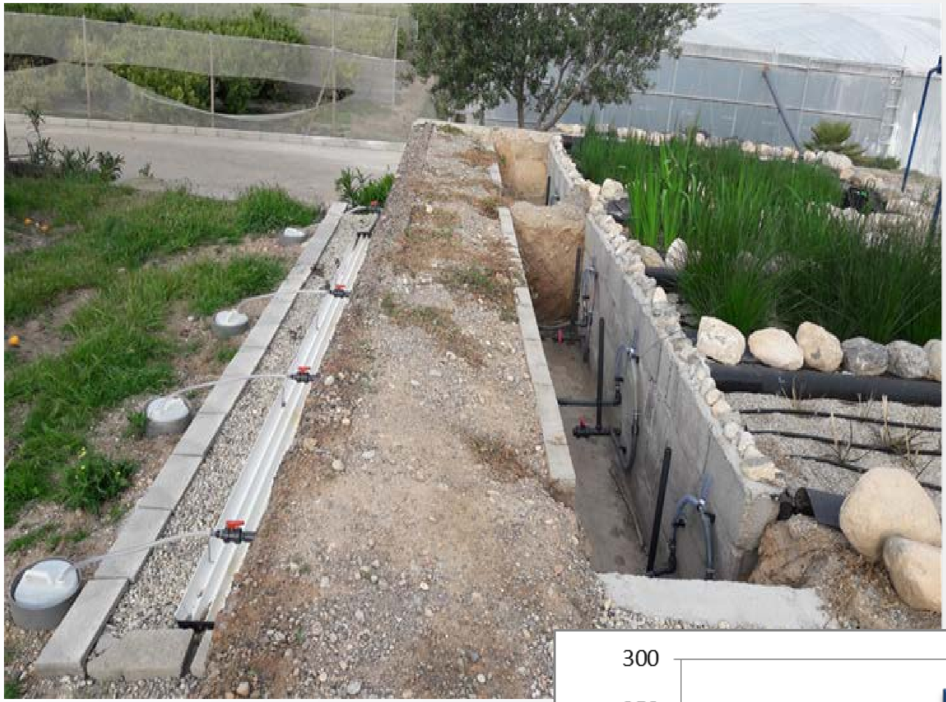


NO_3^- reduction: 89-95%

Medrano et al. (2018)

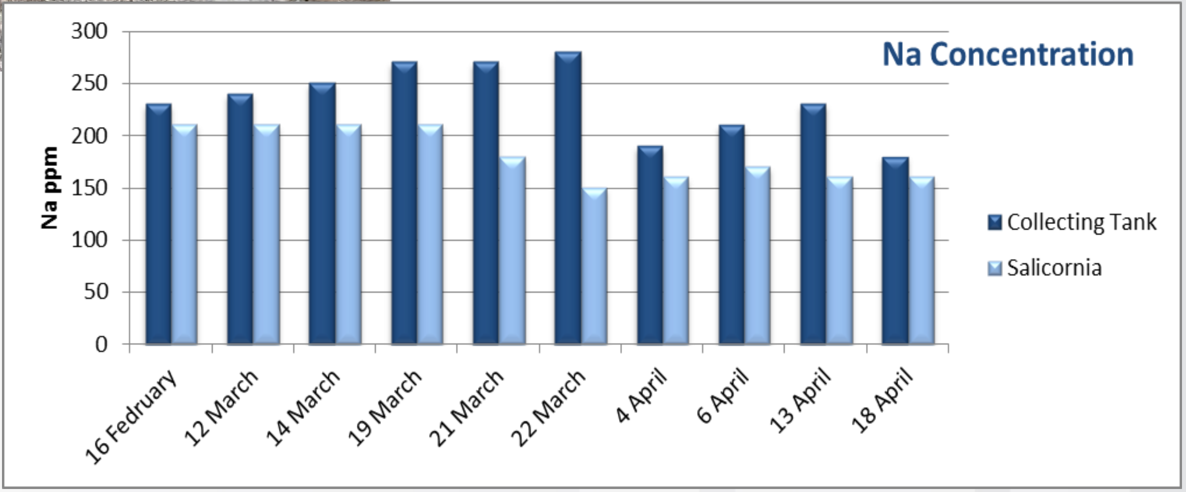


Evaluation of CLEANLEACH system to recover and purify leachates of agricultural origin by artificial lagoon



Na reduction: 13-46%

Medrano et al. (2018)



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Thank you very much