University of Thessaly

IRRIGATION OF A HYDROPONIC CROP BASED ON REAL TIME DRAINAGE MEASUREMENTS

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Laboratory activity

- Soil and Soilless production of ornamental plants
- Use of innovative techniques for ornamental plant production
- Use of bio stimulants
- Landscape Architecture

The significance of the proper irrigation schedule

- ➢Cover crop water needs
- ➢Cover crop nutrients needs
- ➢Maintain adequate substrate moisture
- ➢Prevent salt accumulation in the substrate
- ➢Promote substrate aeration
- ➢Reduce substrate temperature
- ➢Save energy

Irrigation schedule basic futures

IRRIGATION DOSE

The amount of nutrient solution supplied to cover crops’ water needs

Estimated: $Q = \frac{T_r}{(1 - D)}$

D is the drainage rate and

Tr is the crop transpiration

IRRIGATION DURATION

The duration of each irrigation cycle

Estimated: $t = \frac{Q}{q*n}$*3600

t = duration of each irrigation cycle in sec

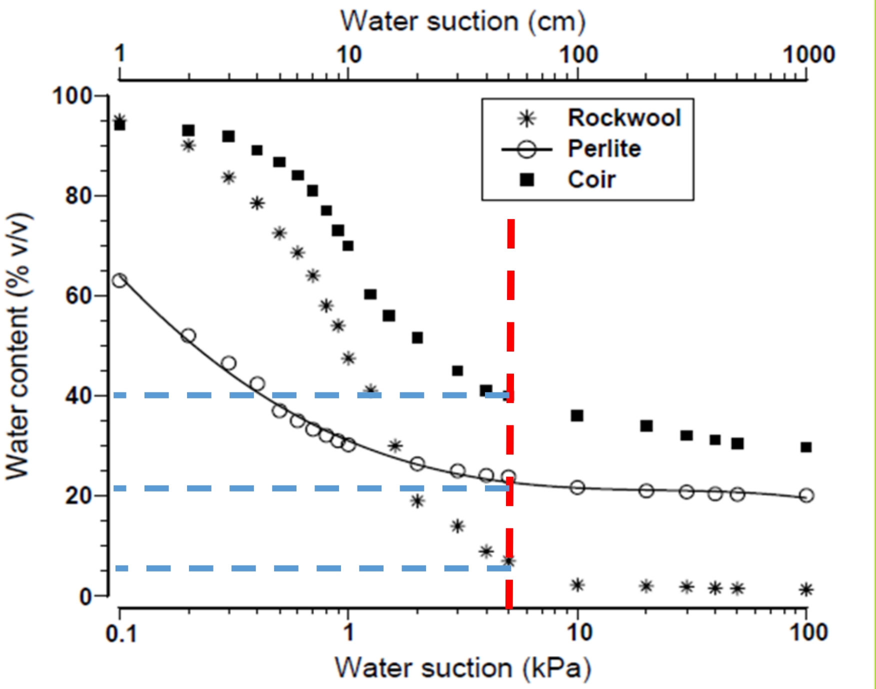
E= irrigation dose

q= water supply of each dripper

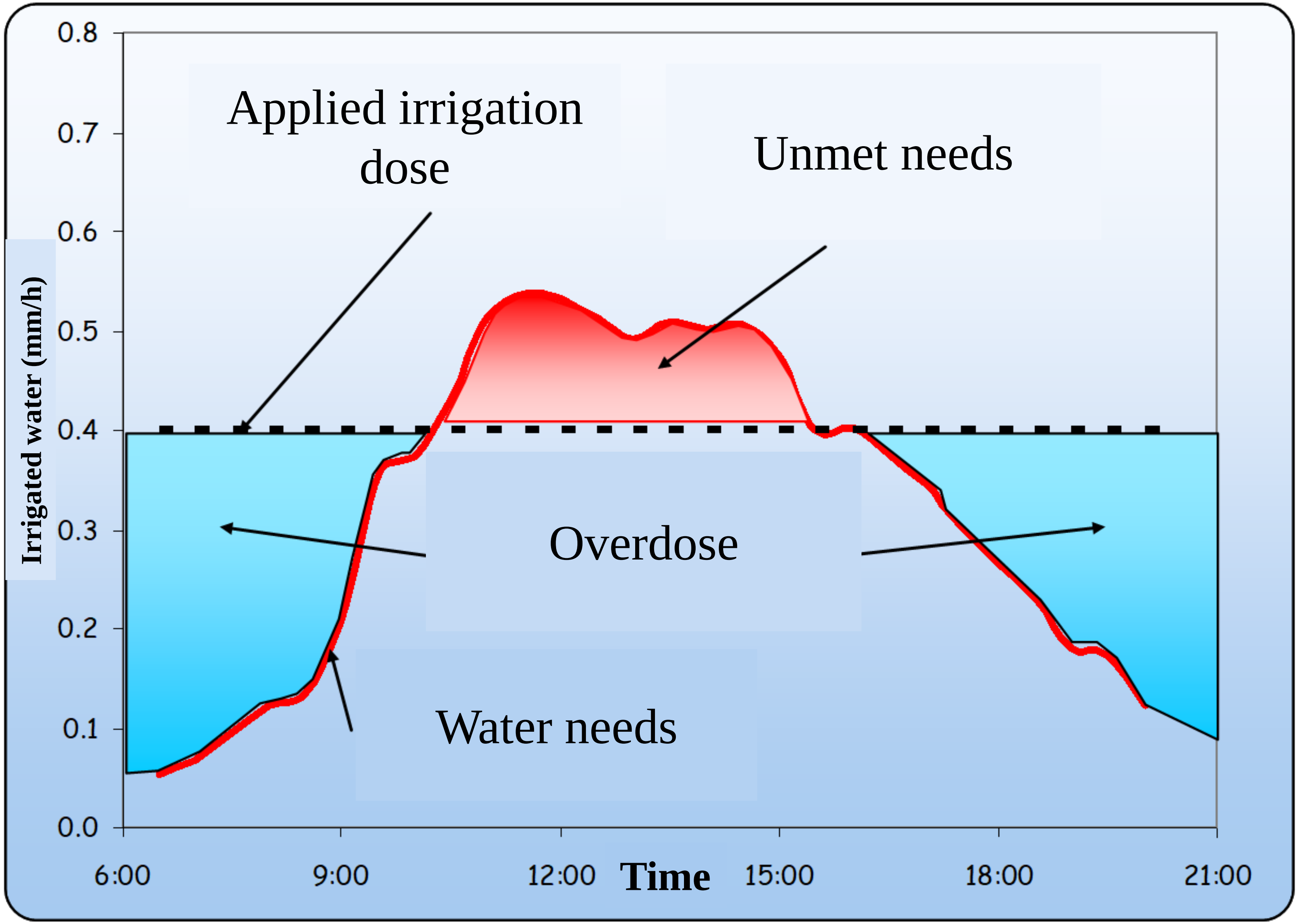
n= number of drippers

IRRIGATION FREQUENCY

The timing of an irrigation event

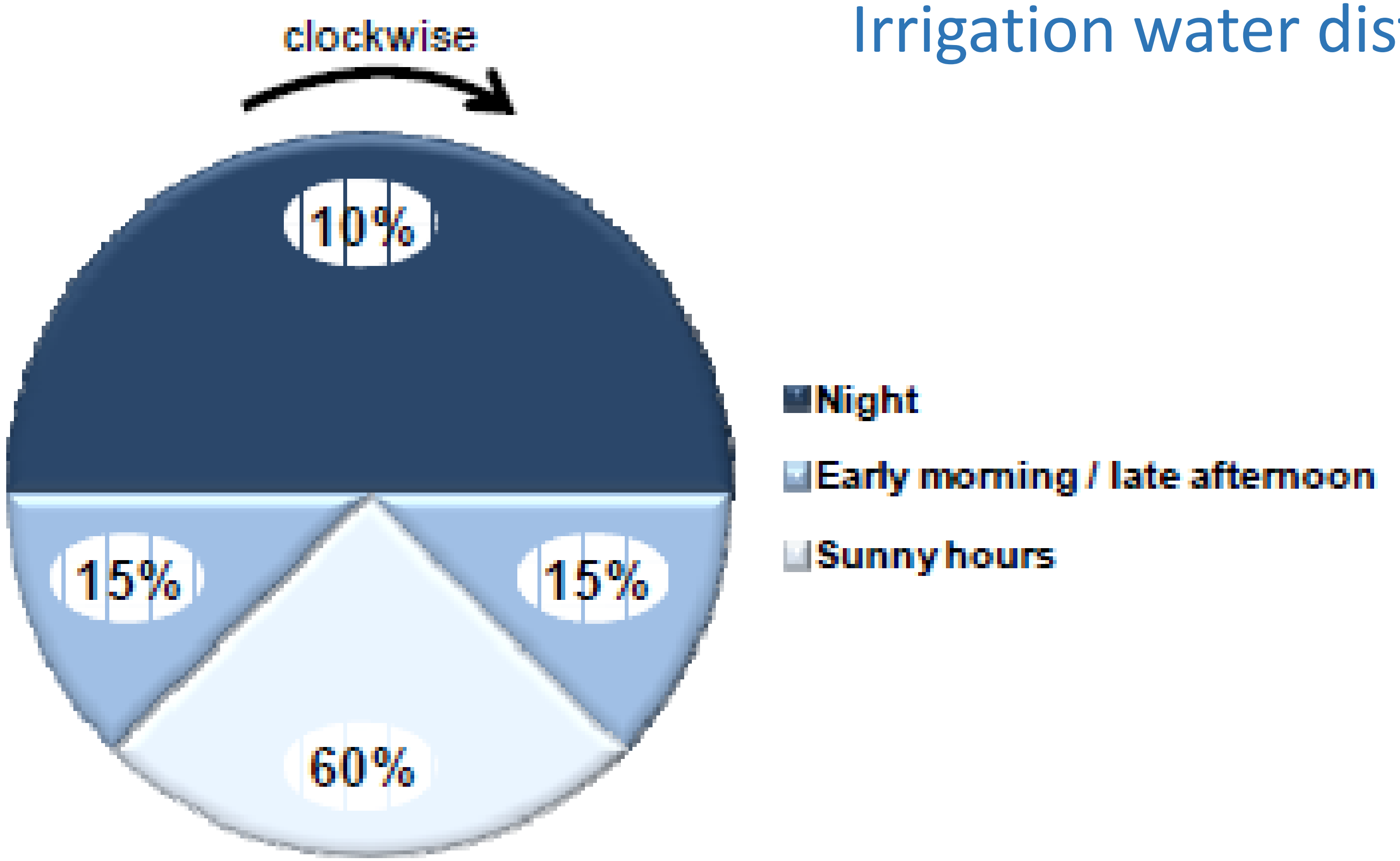


THE ERROR OF A TIME CLOCK BASED IRRIGATION SCHEDULE



TIME CLOCK BASED IRRIGATION

Irrigation water distribution during 24h



EVALUATING THE IRRIGATION DOSE ACCORDING TO CROP NEEDS

METHODS TO ESTIMATE CROP TRANSPIRATION

Estimation of plants TRanspiration

$$TR = a*RG + b*VPD$$

$$TR = \zeta*RGo$$

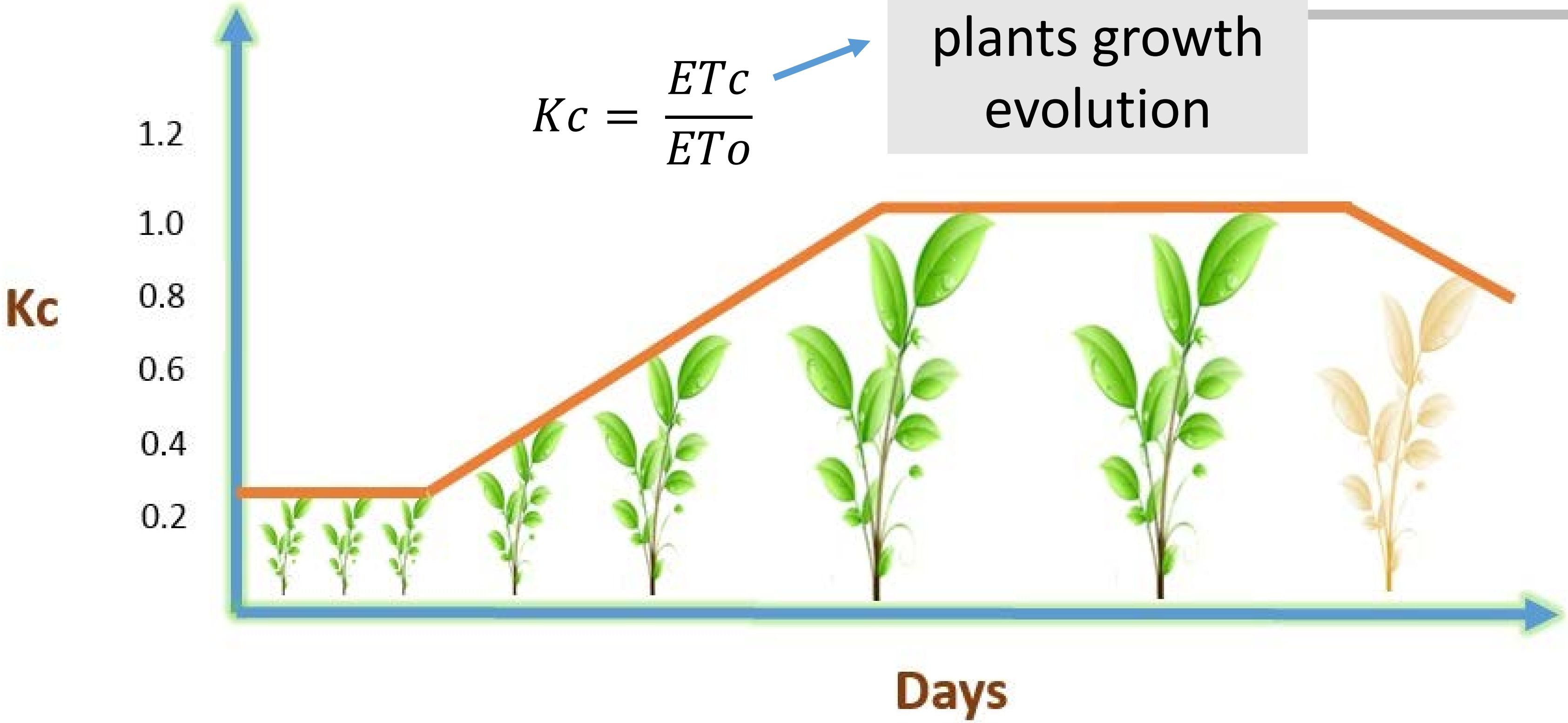
$$\zeta = Kc*\tau*\alpha/\lambda$$

TR in kgm^{-2}
a, b = coefficients determined by statistical adjustment
RG = Solar radiation in (Wm^{-2})
VPD = Vapor Pressure Deficit in (kPa)
RGo = accumulative solar radiation outside the greenhouse (kJm^{-2})
τ = greenhouse cover transmission to solar radiation
α = evaporation coefficient (0,6 for greenhouse crops)
λ = latent heat of vaporization of water in $kJ\ kg^{-1}$
Kc = crop coefficient

Kc is the ratio of the evapotranspiration of the crop (ET_C) to a reference crop (ET_O) which may be measured directly from a reference crop such as a perennial grass

$$Kc = \frac{ETc}{ETo}$$

plants growth evolution



Factors affecting plants growth evolution

- Cultivation treatments
- Climate parameters

APPLICATION BASED ON ACCURACY OF THE MODEL

Medium and high technology greenhouse

Greenhouse description	ET model	Accuracy	Greenhouse crop
Natural ventilation	Stanghellini	$r^2=0.72$	Tomato
	Energy balance equation	$r^2=0.68$	Tomato
	FAO Penman-Monteith	$r^2=0.62$	Tomato
Controlled environment	Stanghellini	$r^2=0.96$	Tomato
	Fynn	$r^2=0.94$	Chrysanthemum
	Simplified model	$r^2=0.87-0.97$	Ornamental species

MEASUREMENT DATA FOR EACH ET MODELS

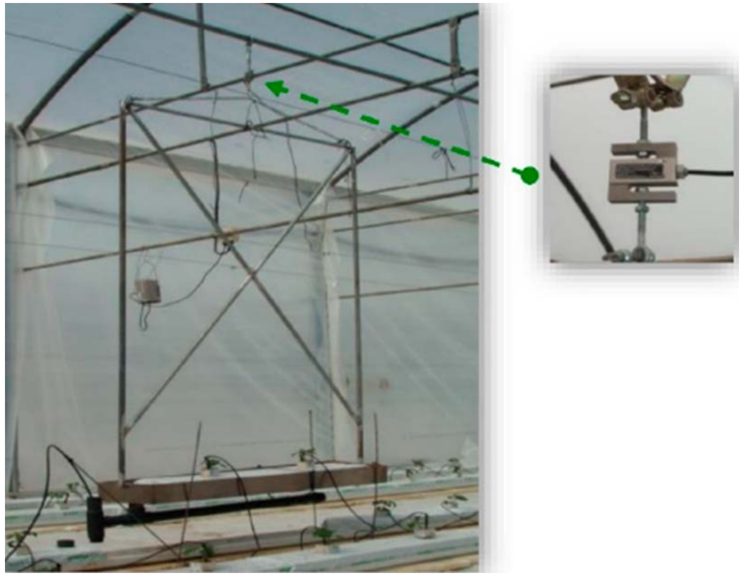
ET models	Data needed						
	Rn	u	Ta	To	Tw	VPD	LAI
Stanghellini	X		X	X		X	X
Energy balance equation	X		X		X		
FAO Penman-Monteith	X	X	X				
Fynn	X					X	X
Simplified model	X					X	

Rn Net radiation, **u** Wind speed, **Ta** Ambient air temperature, **To** Leaf temperature, **Tw** Surface temperature, **VPD** Vapour pressure deficit, **LAI** Leaf area index

PRACTICES FOR MEASURING CROP TRANSPIRATION

Substrate Monitoring

Weighing gutter



Volumetric water content

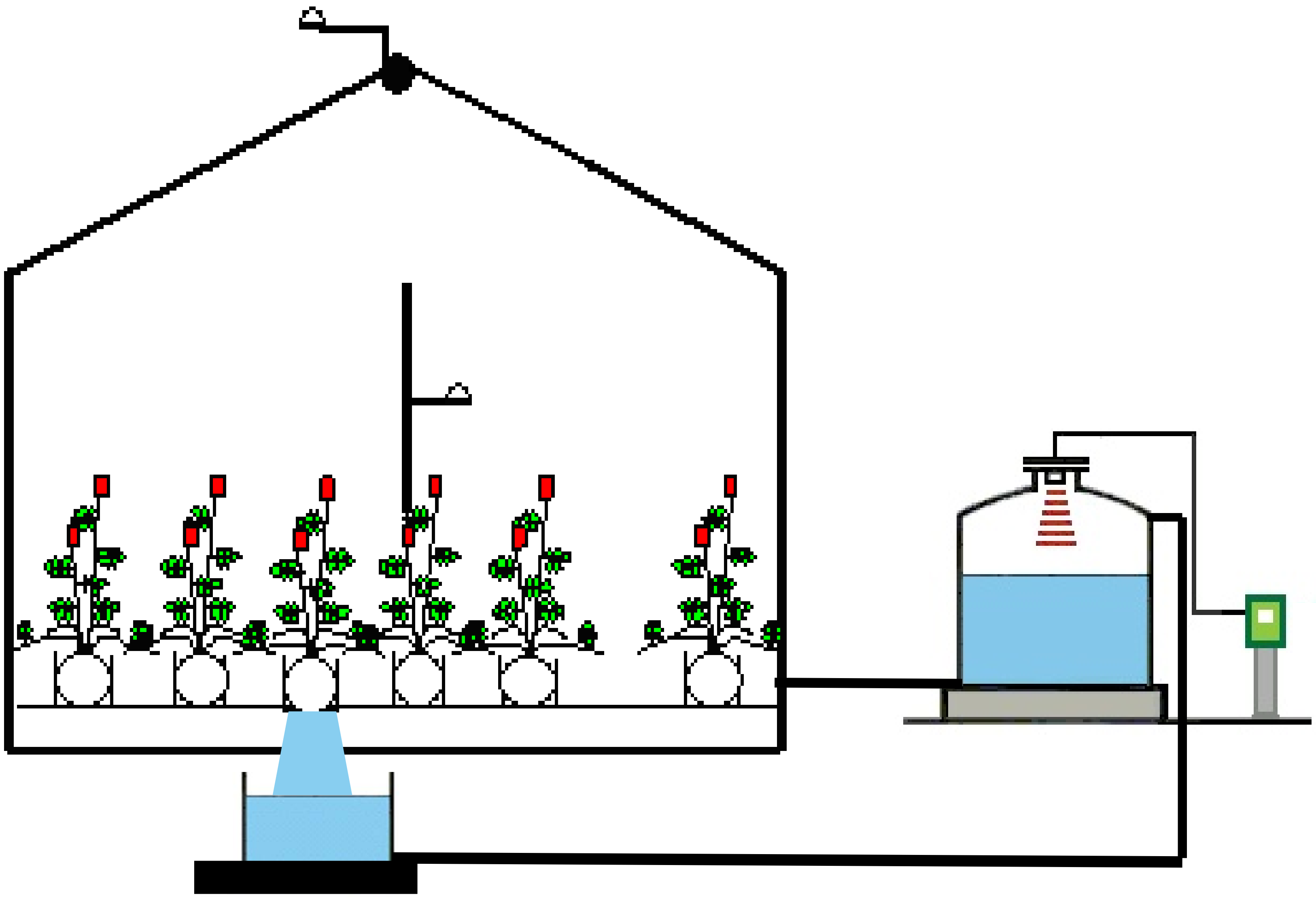
Electrical resistance sensor

Moisture sensors

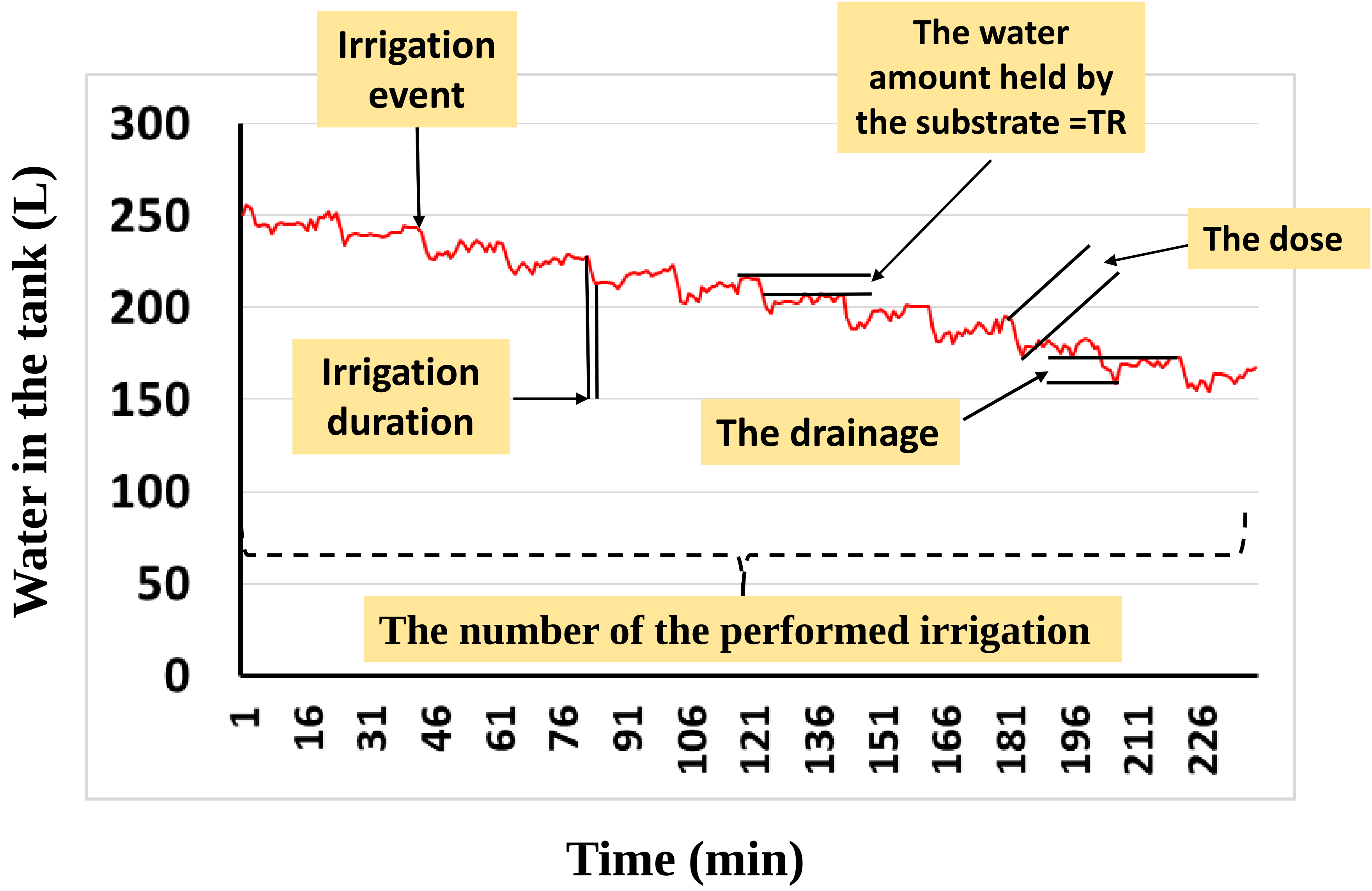
Water potential

Weighing gutter for automated monitoring of crop evapotranspiration and irrigation control in tomato substrate culture (Photo: A. De Koning, Hortimax, Pijnacker, NL).

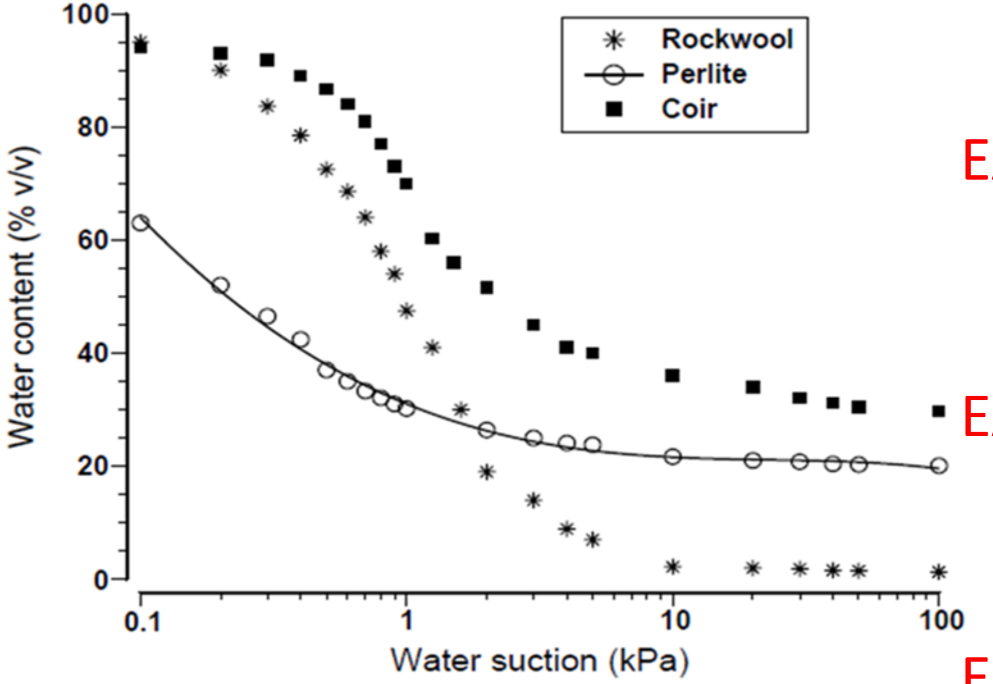
SYSTEM SIMILAR TO THE LYSIMETER



Information taken from the method



EVALUATING THE IRRIGATION FREQUENCY



Volumetric water content at different matric potentials of various growing media as determined in the laboratory. These values are used to draw water retention curve, which is a physical properties of growing media. Air capacity (at -1 kPa) and available water (the difference in water content between –1 and –10 kPa suction) are also reported.

	Matric potential (suction; kPa)							
Substrate	0	-1.0	-3.0	-5.0	-7.5	-10.0	AC (%)	AW (%)
Coconut	93	70	44	40	37	35	23	35
Peat	90	72	46.0	41	37	35	18	37
Perlite	95	35	31	28	25	22	60	13
Pumice	69	41	37	36	35.5	35	28	6
Rockwool	97	82	7	6	5	4	15	78
Peat-perlite	75	54	40	36	33	30	21	24
Peat-pumice	77	51	43	37	35	32	26	19

EAW 30%

EAW 7%

EAW 76%

Substrate Type	Perlite bags	Rockwool slabs	Coco coir bags
Substrate Volume	33 lit	11,25 lit	15 lit
Substrate EAW	2,3 lit	8,55 lit	4,5 lit

Irrigation will be occurred when

TR=EAW

Constant

DURATION OF EACH IRRIGATION CYCLE

Constant irrigation cycle

$$t = \frac{Q}{n * q} * 3600$$

Theoretically constant for each substrate =EAW

t = time (seconds)

Q = irrigation dose (liters per bag)

n = number of drippers per bag

q = water supply of each dripper [L h^{-1}]

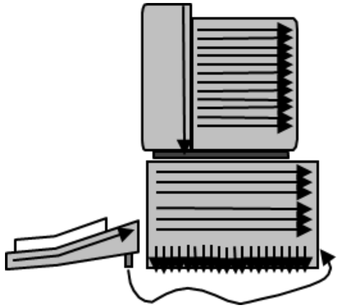
THROUGH THE INCOMING SOLAR RADIATION

$$Etg * \frac{\Sigma RG}{\lambda}$$

$$\left.\begin{aligned} \mathbf{Q} &= \frac{TR}{(1-D)} \\ \mathbf{Q} &= EAWs * n \end{aligned}\right\} \quad \mathrm{Etg} * \Sigma \mathrm{RG} = \mathrm{EAWs} * n * \lambda * (1-\mathrm{D}) \Rightarrow \Sigma \mathrm{RG} = \frac{EAWs * n * \lambda * (1-D)}{Etg}$$

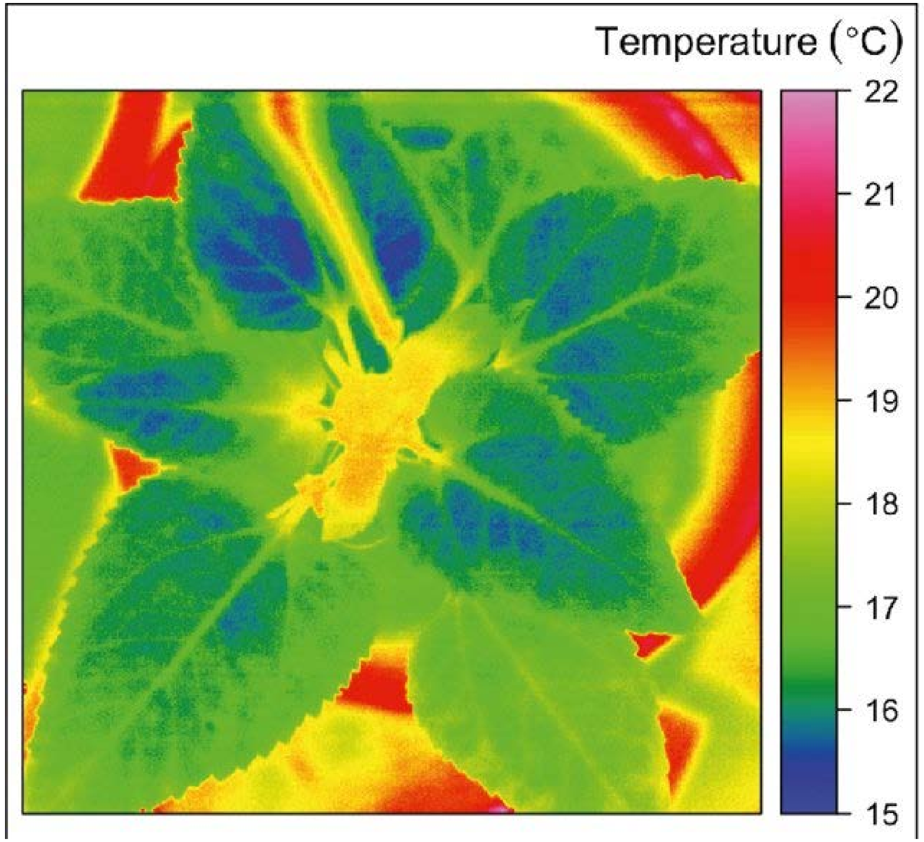
ΣRG, sum of income to the greenhouse solar energy (J m^{-2})
Etg, percentage of solar radiation spent for transpiration (AV=0.65 for greenhouse crops)
EAWs, easy available water [liters sac^{-1}].
n, the number of bags m^{-2}.
λ, the latent heat of vaporization of water
dr, the percentage of runoff

$$\Sigma RG = \frac{Q*n*\lambda*(1-D)}{Etg}$$

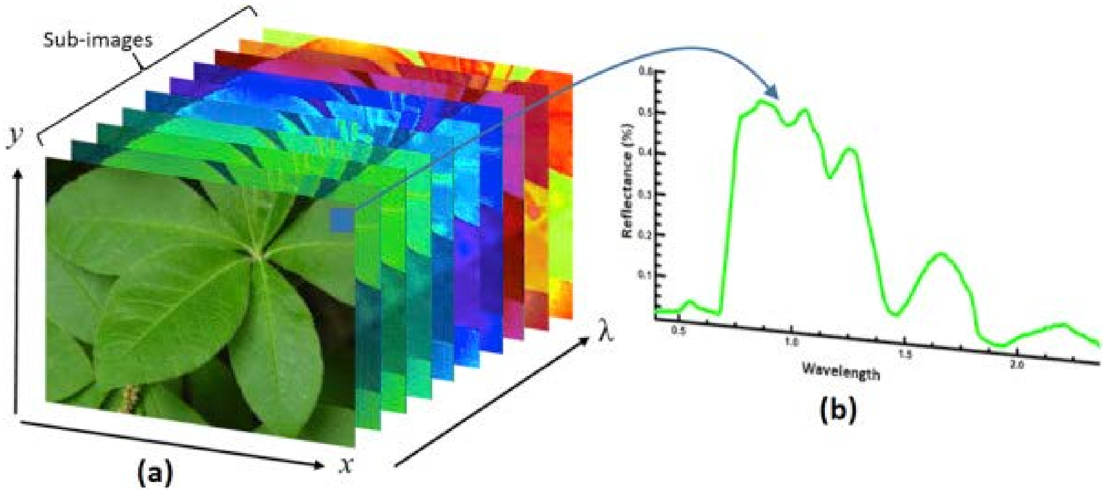


OTHER PRACTICES TO DETERMINE IRRIGATION FREQUENCY

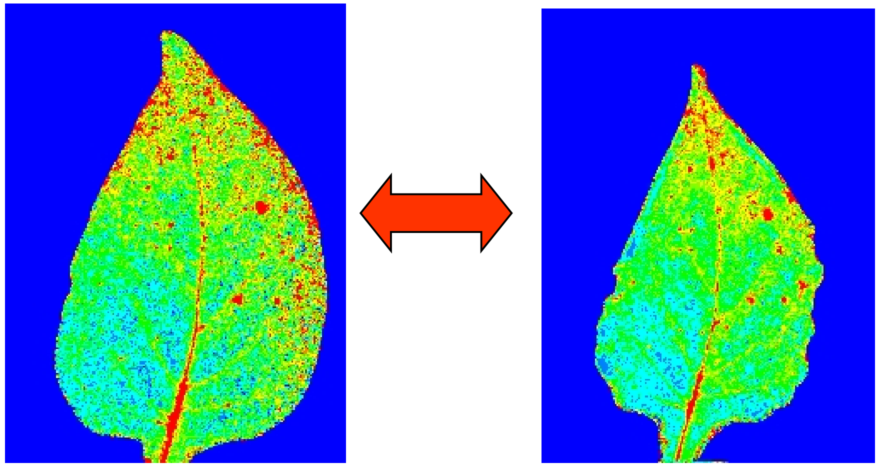
MEASURING LEAF TEMPERATURE



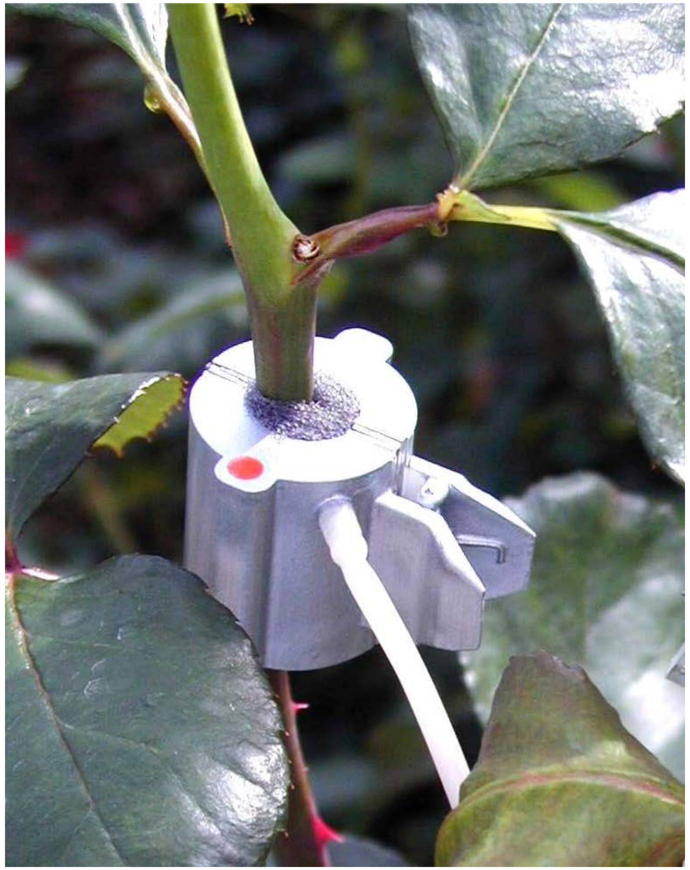
THROUGH HYPERSPECTRAL IMAGES



85 % H_2O 65 % H_2O

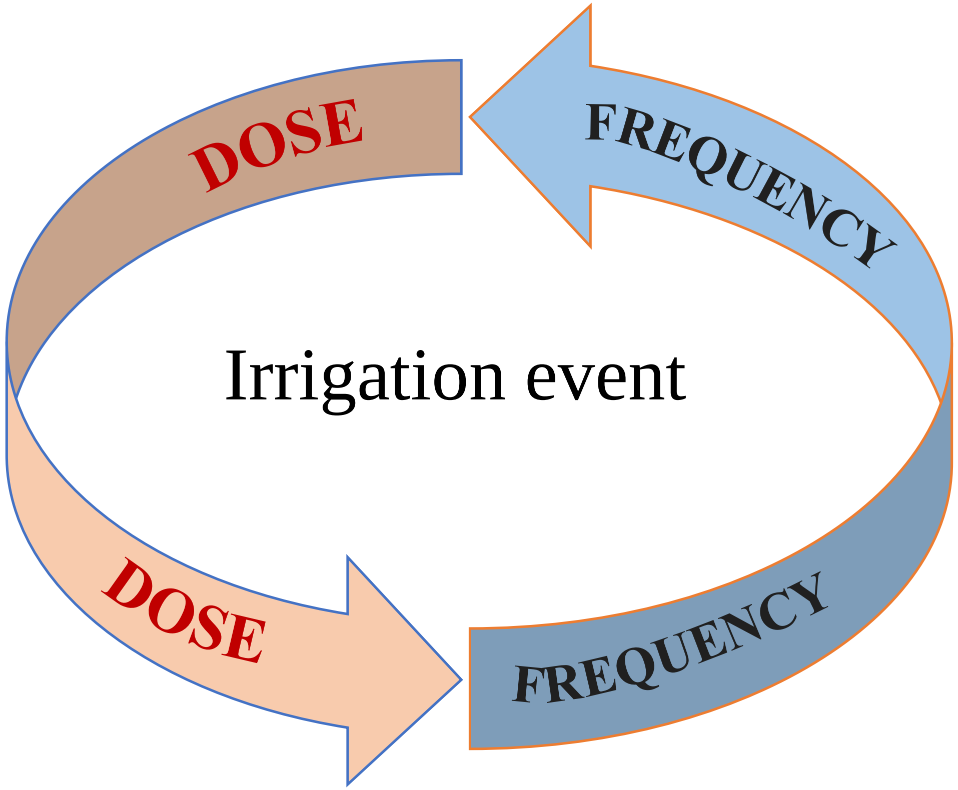


THROUGH PHYTO-SENSING



Sap flow sensor
(heat balance and thermal dissipation)

Leaf sensor for simultaneously measure of leaf thickness and leaf electrical capacitance to monitor water stress in plants.


DOSE
FREQUENCY
Irrigation event
DOSE
FREQUENCY

ESTIMATIONS VS MEASUREMENTS

Estimating Transpiration

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- Easy and flexible
- Concerns the whole crop
- Based on simple climate parameters
- Low cost
- Values represent physical characteristics
- Combined with other models

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- Unreliable under circumstances
- A great number of measurements are needed
- Based on coefficients calculated by statistical identification
- Differs depending on plant species, location etc.
- In question if really happens

Measuring Transpiration

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- Reliable
- One parameter is usually measured
- Some measurements are enough
- Independent of plant species, location etc.

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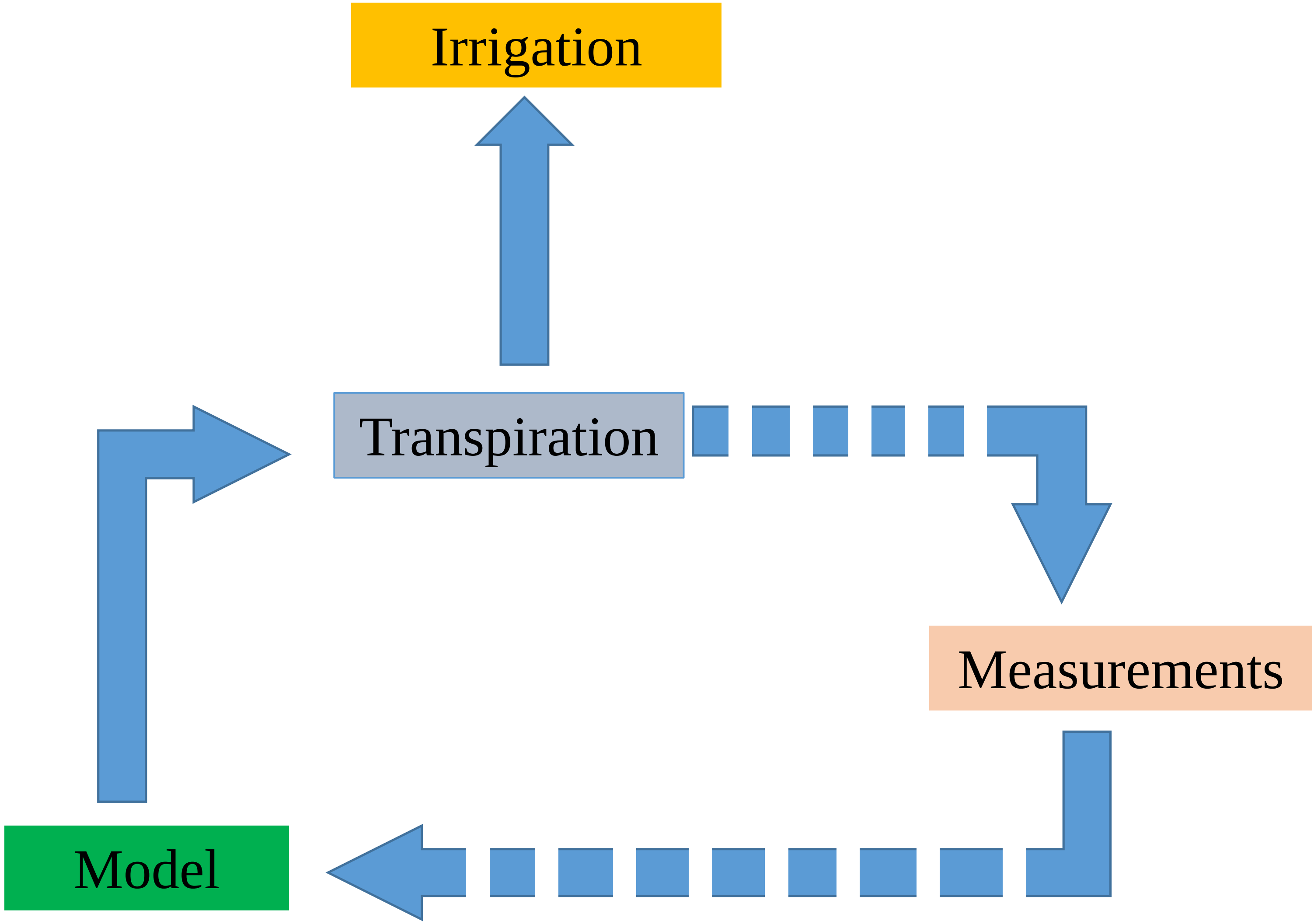
- Concerns only a number of plants
- Cost of equipment and maintenance
- A grate number of sensors is necessary to cover the whole greenhouse

COMPINATION OF ESTIMATIONS AND MEASUREMENTS



SET THE PROBLEM

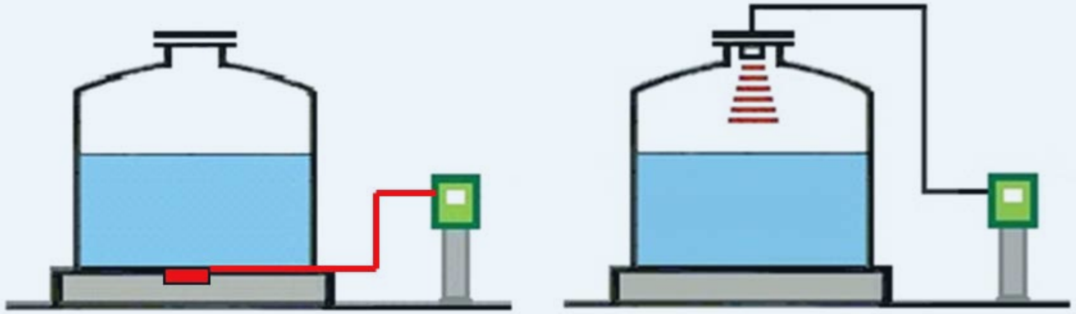
ASSUMPTIONS for a good evaluation of irrigation which is based on TR

- **The transpiration model is reliable**
- **If transpiration is measured, this should be done in many places inside the greenhouse**
- **The characteristics of the substrate remain stable**

HOW THE DRAINAGE MEASUREMENTS ALREADY USED FOR IRRIGATION CONTROL

Flowmeter

Estimating the volume



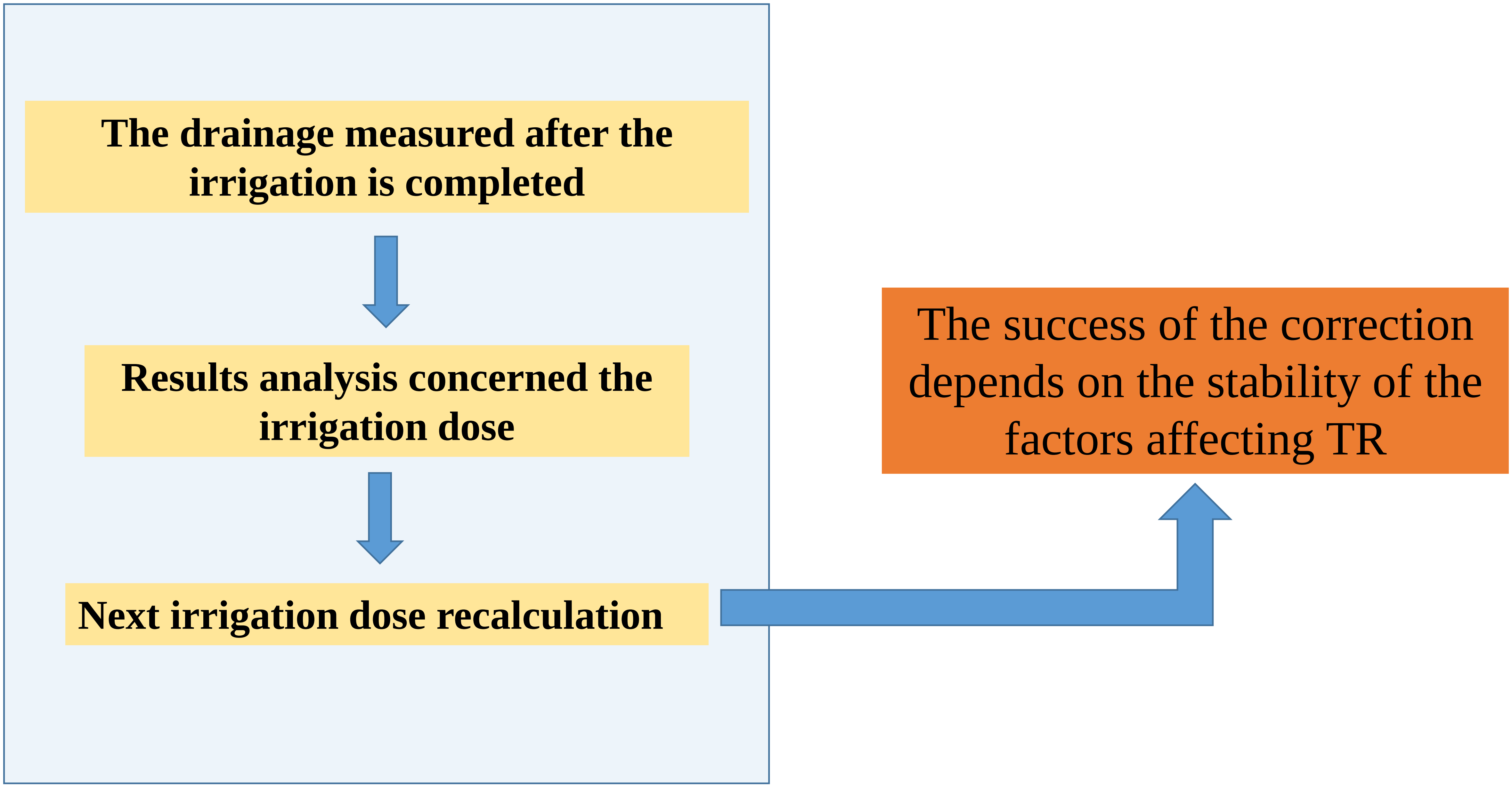
The drainage measured after the irrigation is completed

↓

Results analysis concerned the irrigation dose

↓

Next irrigation dose recalculation


The drainage measured after the irrigation is completed
Results analysis concerned the irrigation dose
Next irrigation dose recalculation
The success of the correction depends on the stability of the factors affecting TR

Develop a drainage measurement methodology to utilize the results in real time

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Optimization of current irrigation

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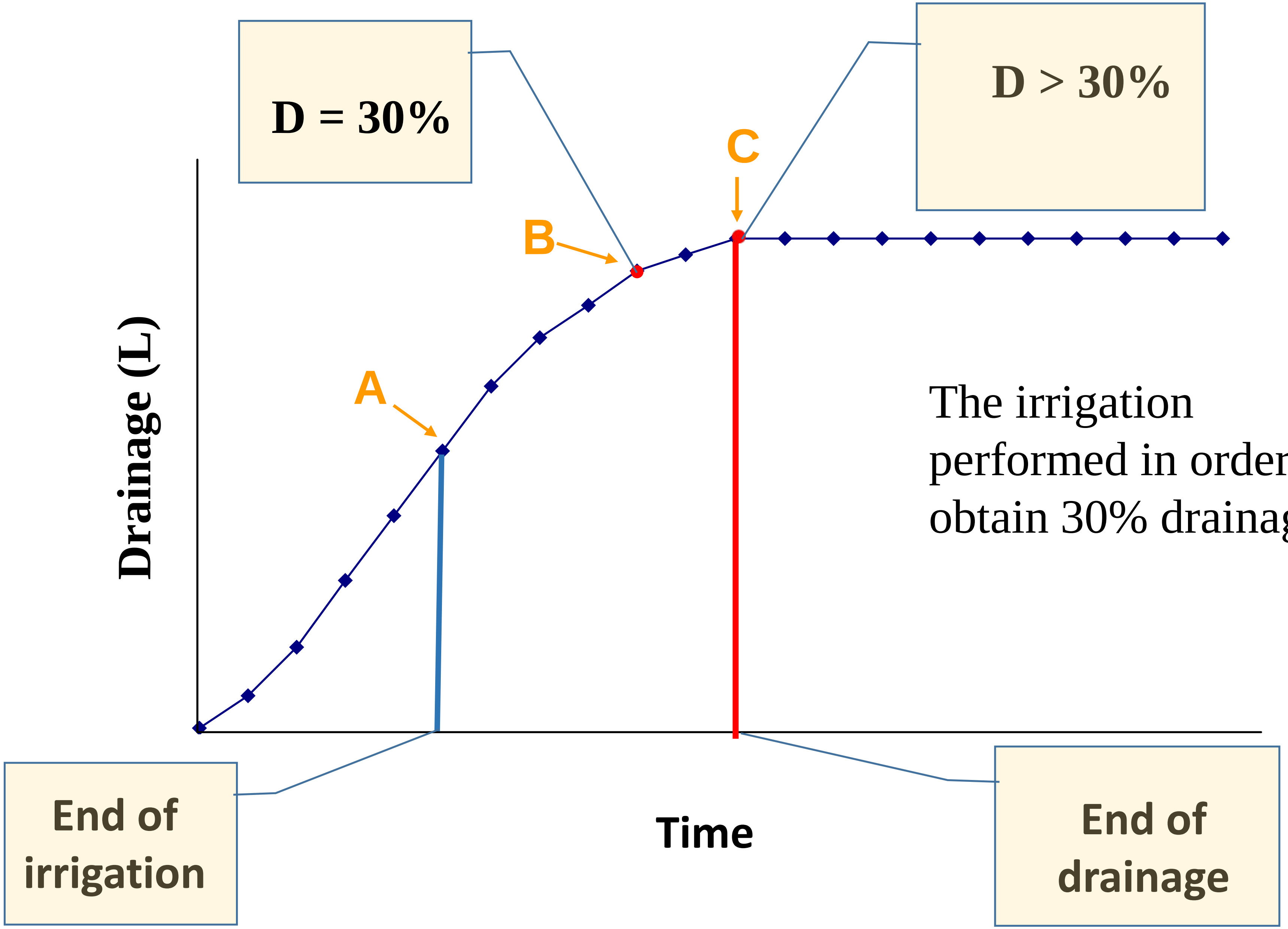
Ensure proper dose and frequency of irrigation

ANALYZING THE DRAINAGE



The irrigation performed in order to obtain 30% drainage

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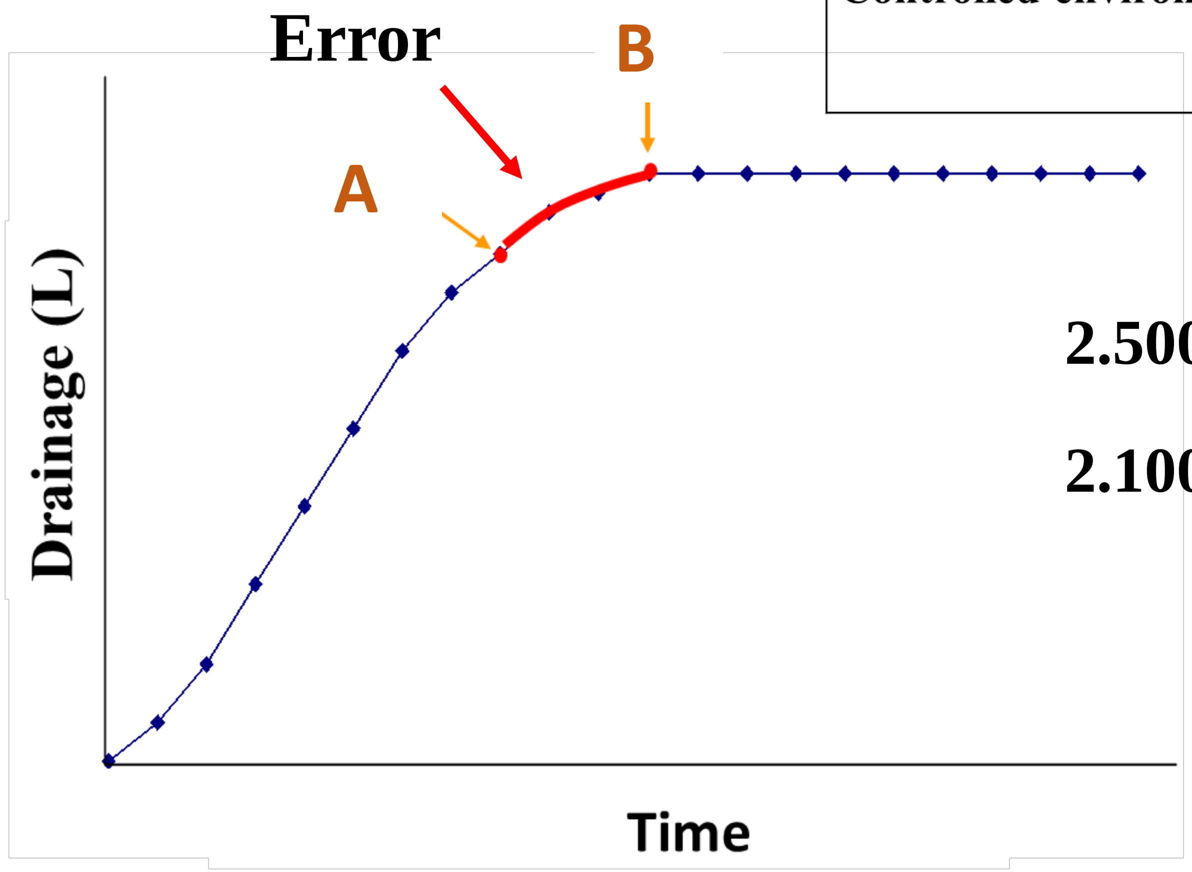
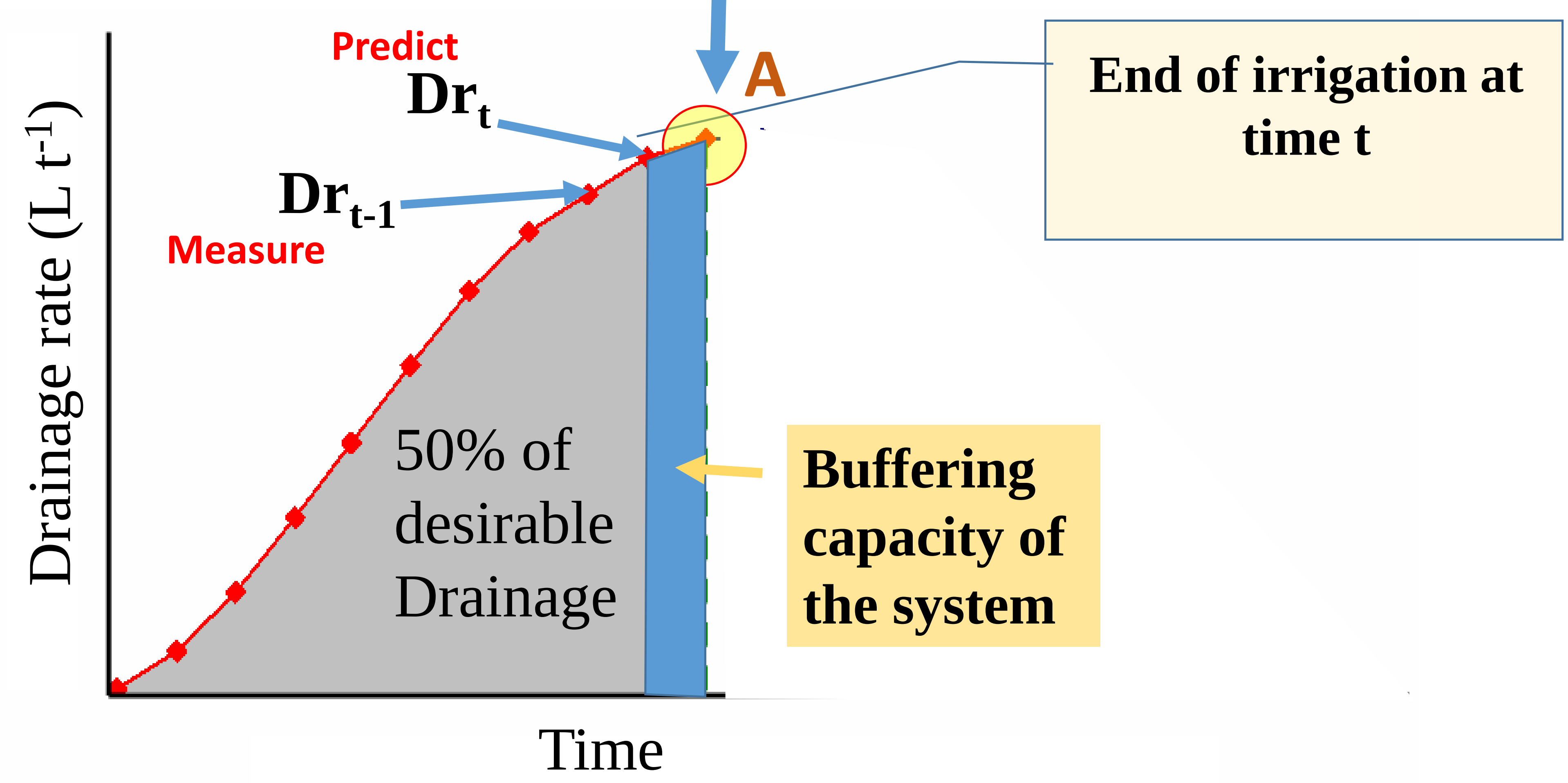


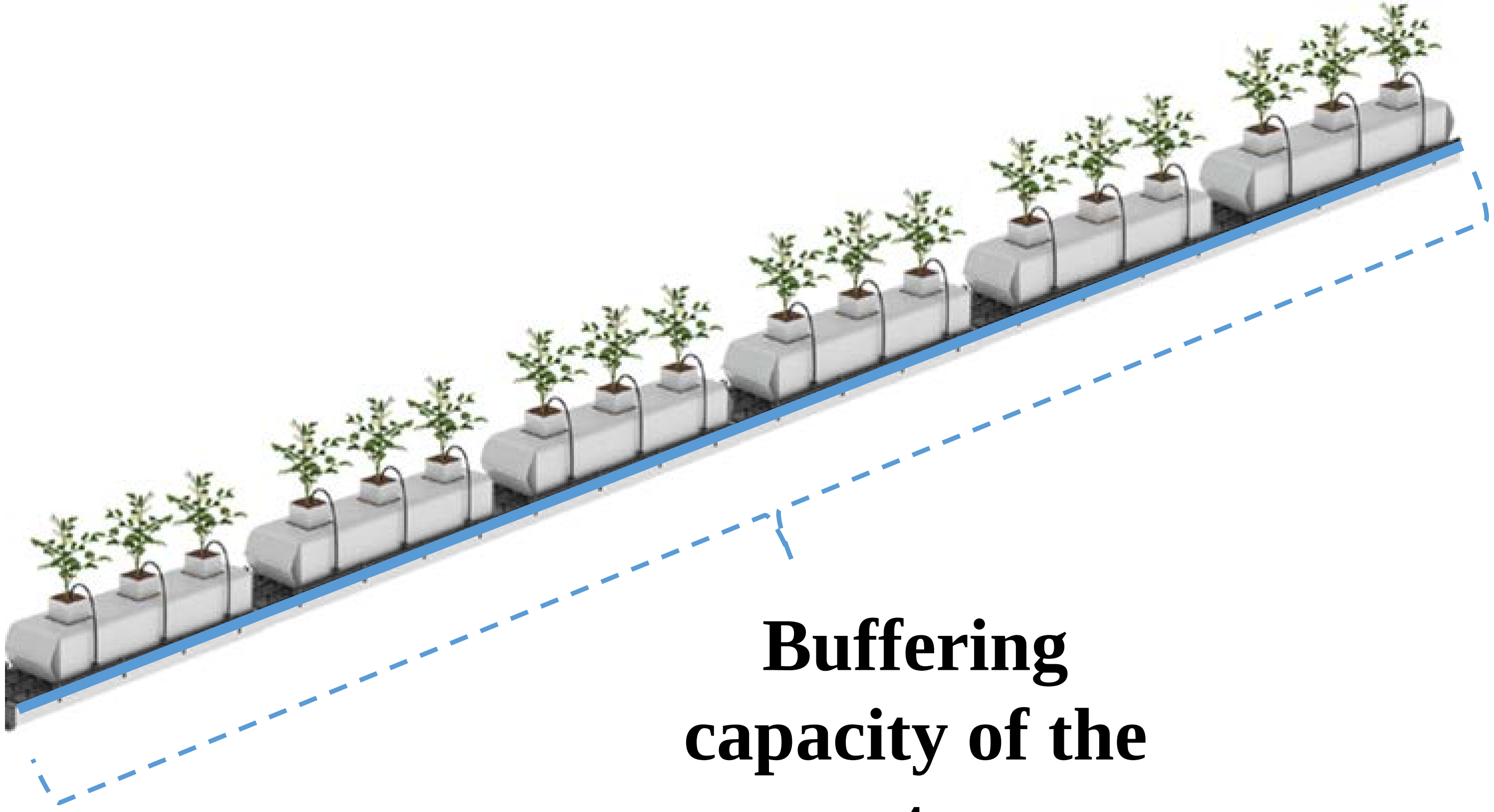
2.500 – 23.700 L day^{-1} ha^{-1} for tomato crop

2.100 – 16.500 L day^{-1} ha^{-1} for ornamental crop

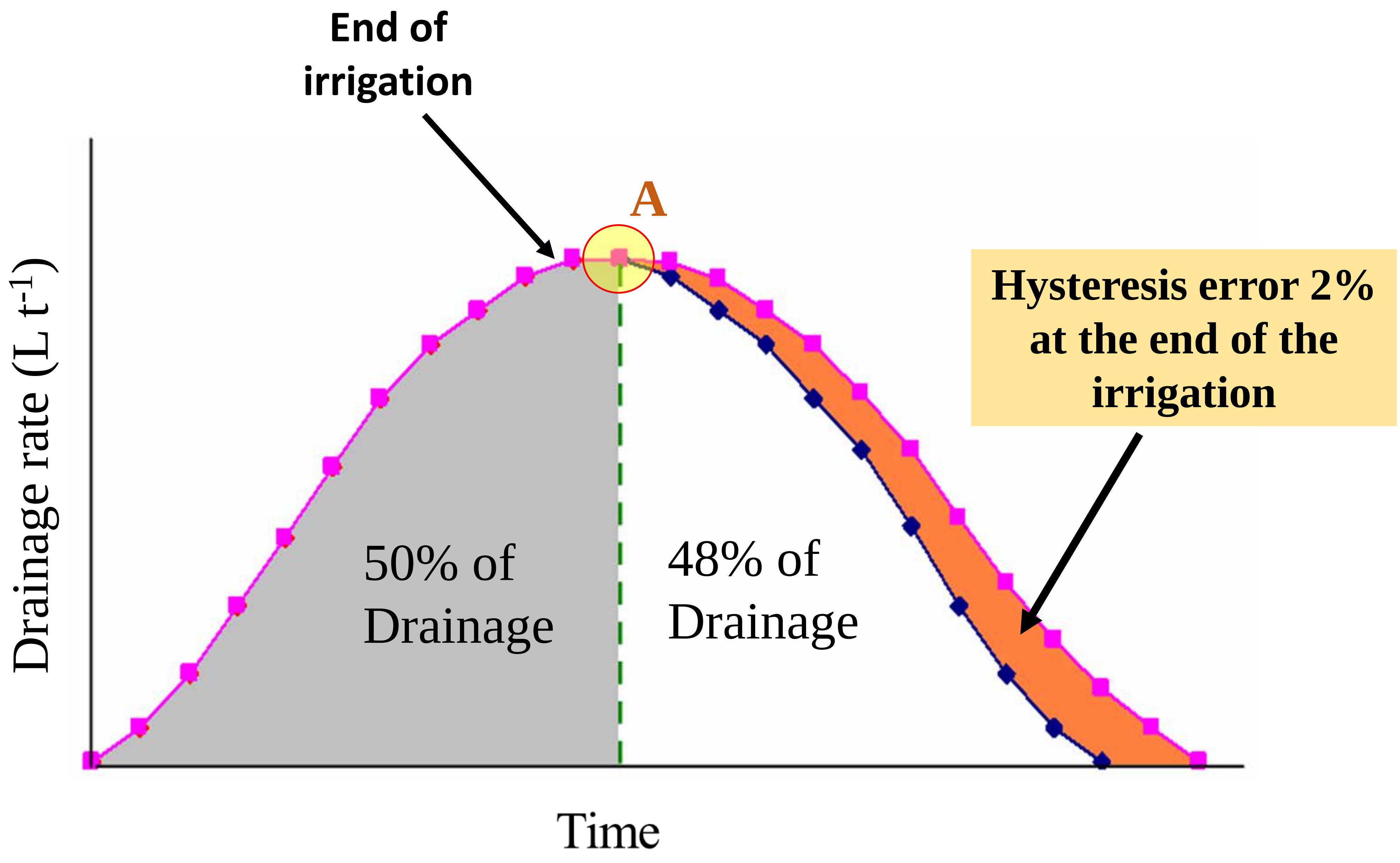
MEASURING THE DRAINAGE AND ESTIMATING THE DRAINAGE RATE (DR) DEFINE THE TIME TO END THE IRRIGATION

$$Dr_{t+1}=Dr_t+(Dr_t - Dr_{t-1}) \text{ and } D_{t+1}=D_t+Dr_{t+1}*t_{int}= 0,5*Q$$





Buffering capacity of the system


End of irrigation
A
Hysteresis error 2% at the end of the irrigation
Drainage rate (L t-1)
50% of Drainage
48% of Drainage
Time

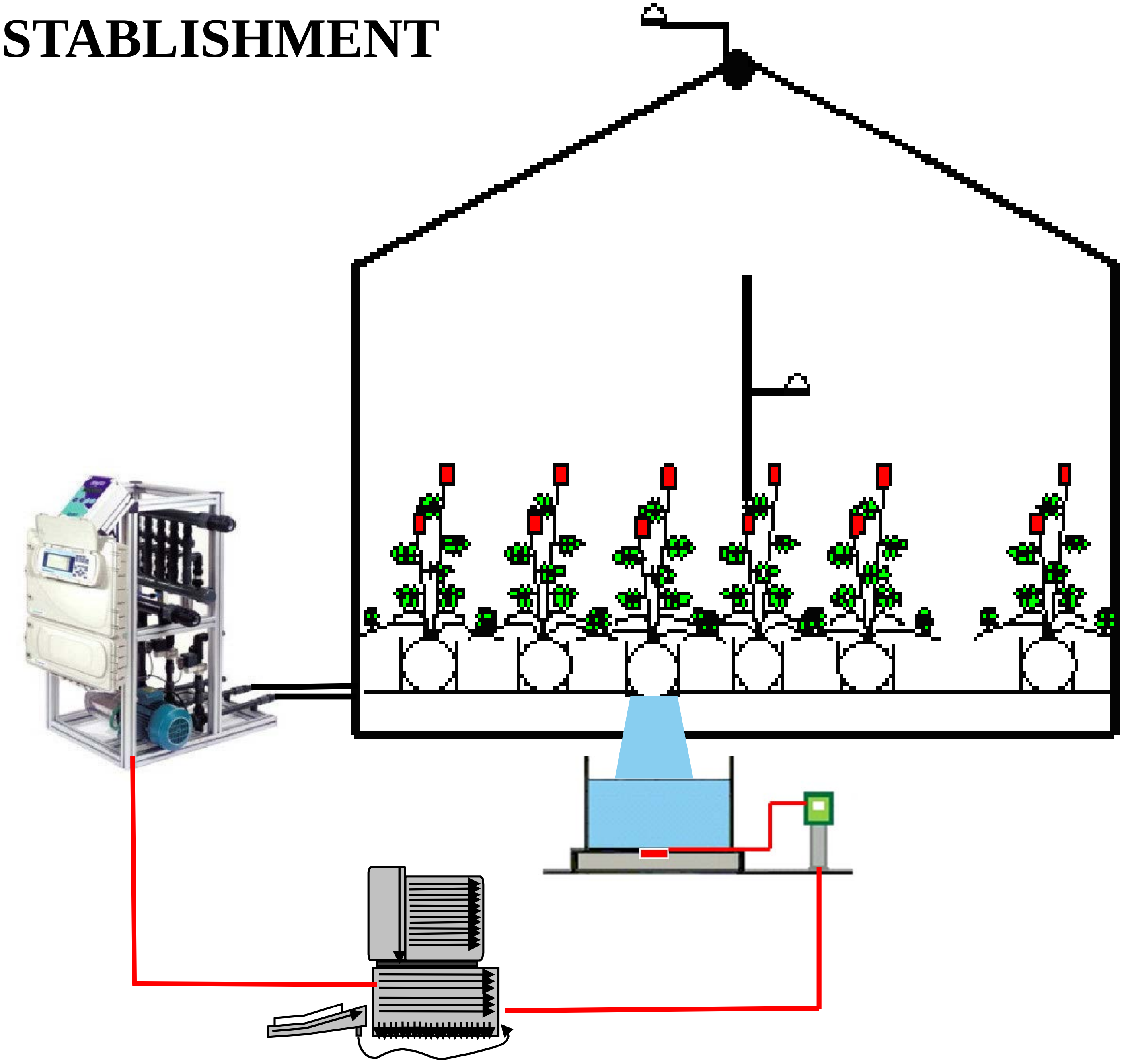
HYSTERESIS ERROR

Should be attributed to:

- **The substrate characteristics**
- **The length of the cultivation channels**
- **The inclination of the cultivation channels**
- **The number and the size of slabs drain hole slits**

The hysteresis error will be estimated once and can be integrated into the calculations

THE SYSTEM ESTABLISHMENT



THE ADVANTAGES OF THE METHOD

- The **accuracy** of the method is very high (98%)
- **Simple** measurements are needed
- **No need** of any transpiration model
- Plants physiological parameters, climate parameters, cultivation treatment, substrate characteristics as well as the type of the greenhouse **do not** affect the methods accuracy
- Measurements concern **a very high number** of plants and can be taken **in many places** inside the greenhouse

THANK YOU FOR YOUR ATTENTION