FERTIGATION INHYDROPONICS

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Soilless culture systems

I. Water culture or hydroponic systems

NFT

Float hydroponics

Aeroponics

Soilless culture systems
II. Substrate Culture

Sand culture

Gravel culture

Soilless culture systems
II. Substrate Culture
Bag culture

Bags filled with pumice

Bags filled with rockwool slabs

Bags filled with perlite

Bags filled with coir

Soilless culture systems
II. Substrate Culture

container culture

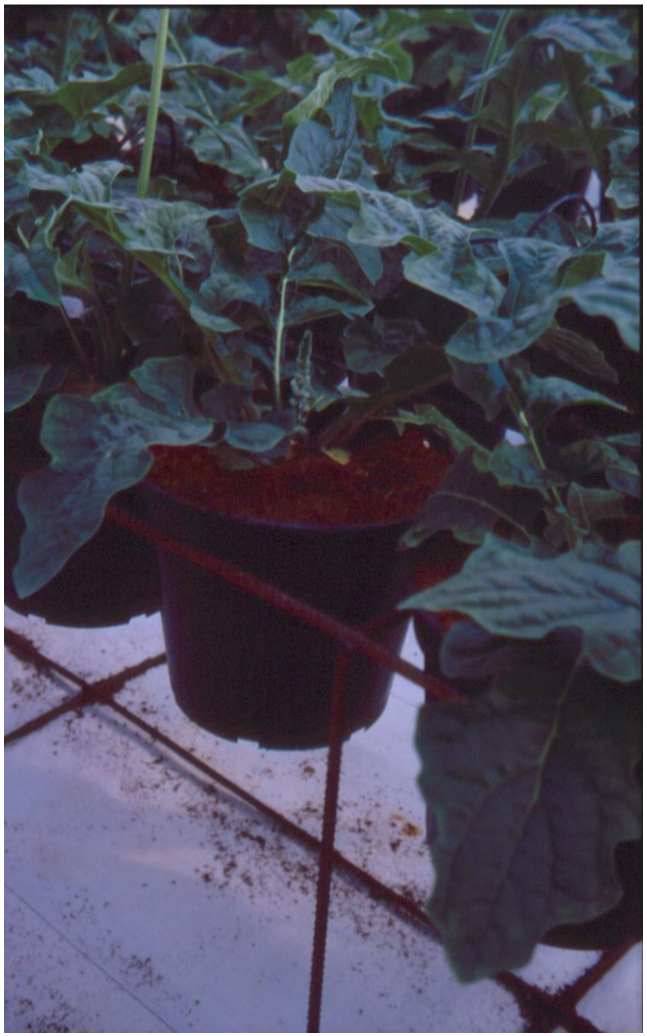
trough culture

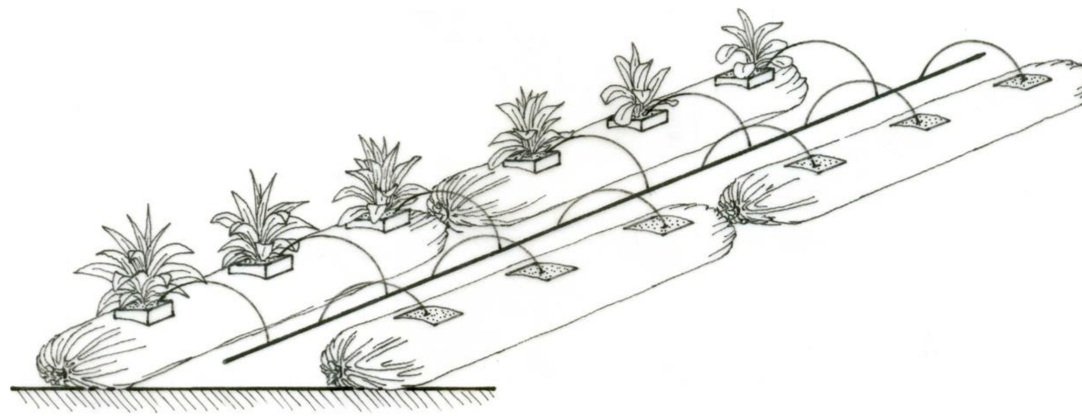
Classification of soilless culture systems according to the method of managing the drainage solution

- **Open soilless culture systems: the drainage solution is discharged**

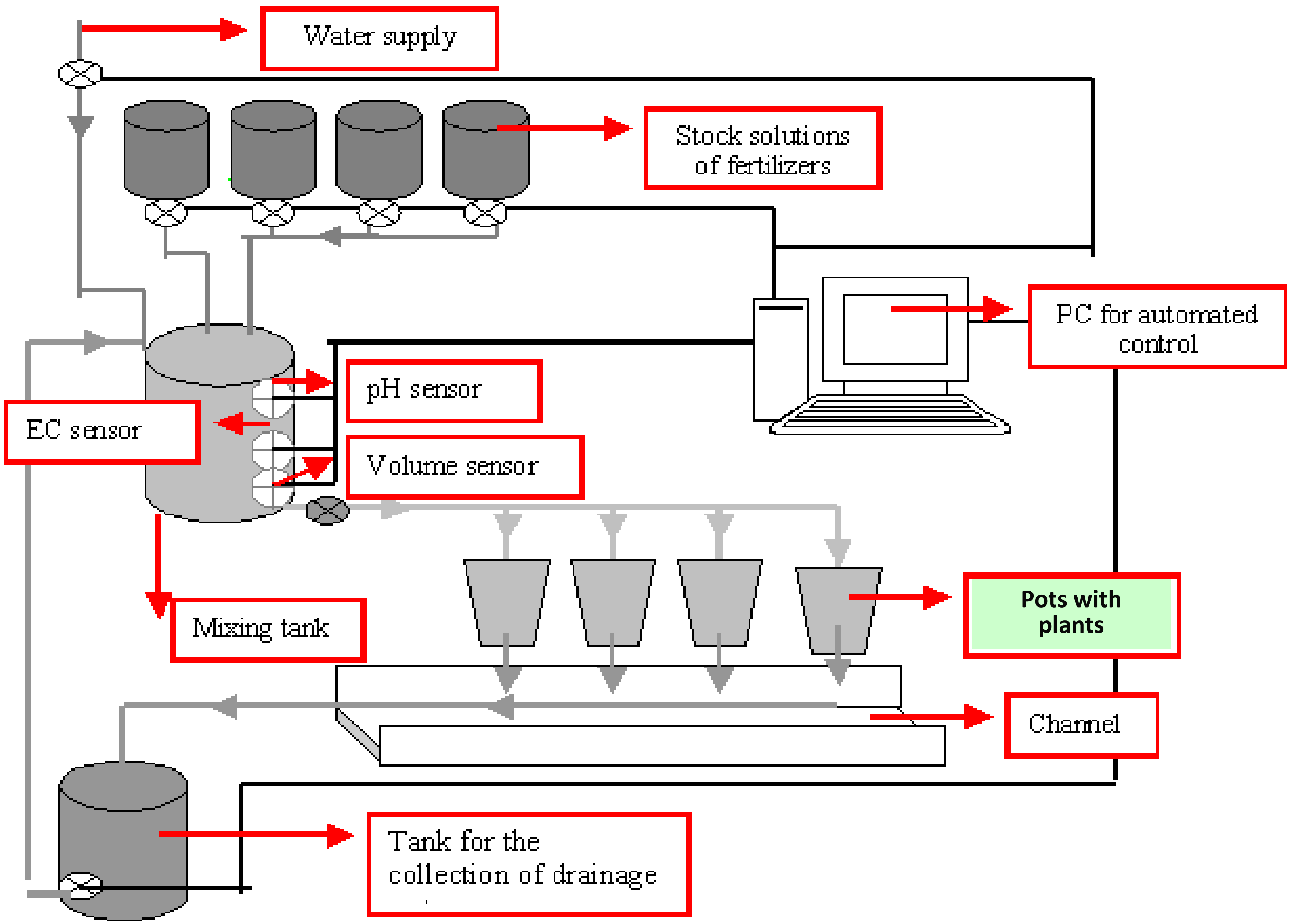
- **Closed soilless culture systems: the drainage solution is collected and recycled**

Open soilless culture systems



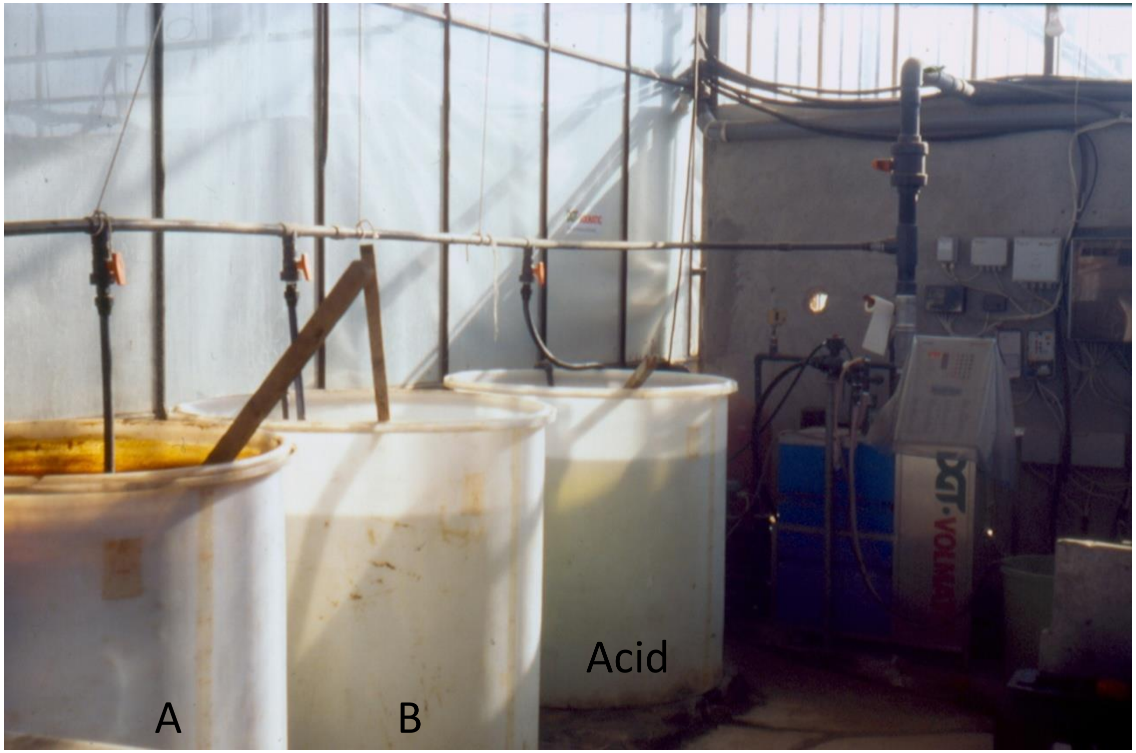


Schematic representation of a closed hydroponic system



Equipment for fertigation system typically comprises:

- Pressure regulators
- Filters
- Tanks for both stock and acid solution
- Fertilizer injection devices



An installation for automated nutrient solution preparation comprising two stock solutions of fertilizers and one stock solution of an acid.

A fully automated installation for nutrient solution preparation and supply with a separated stock solution tank for each fertilizer.

Typical compositions of nutrient solutions for soilless culture

Macro-nutrient	Mmol L^{-1} Hoagland & Arnon	Sonneveld &Straver, cucumber	Sonneveld &Straver, roses	Micro-nutrient	$\mu mol\ L^{-1}$ Hoagland & Arnon	Sonneveld &Straver, cucumber	Sonneveld &Straver, roses
NO_3^-	14.0	16.00	11.00	Fe	25.00	15.00	25.00
$H_2PO_4^-$	1.0	1.25	1.25	Mn	9.10	10.00	5.00
SO_4^{2-}	2.0	1.375	1.25	Zn	0.75	5.00	3.50
K^+	6.0	8.00	4.50	Cu	0.30	0.75	0.75
NH_4^+	1.0	1.25	1.50	B	46.30	25.00	20.00
Ca^{2+}	4.0	4.00	3.25	Mo	0.10	0.50	0.50
Mg^{2+}	2.0	1.375	1.125				

Constraints governing the establishment of a nutrient solution composition:

I. Association between anions and cations

The addition of a macronutrient ion imposes addition of another ion of different charge at an 1 : 1 equivalent ratio

⇒

The input of a macronutrient cannot be considered independently of the other macronutrients

An example: Addition of potassium

$$KCl \rightarrow K^+ + Cl^-$$

$$KNO_3 \rightarrow K^+ + NO_3^-$$

$$KH_2PO_4 \rightarrow K^+ + H_2PO_4^-$$

$$K_2SO_4 \rightarrow K^+ + SO_4^{2-}$$

Constraints governing the establishment of a nutrient solution composition:

II. Mineral composition of water

- **In most cases, the irrigation water contains considerable amounts of some:**
  - **macronutrients (Ca, Mg, S-SO_4^{2-}),**
  - **micronutrients (Mn^{2+}, Zn^{2+}, Cu^{2+}, B και Cl^-)**
  - **other macroelements (HCO_3^-, Na^+).**

In some cases the concentrations of the above elements in the irrigation water may approach or even exceed their target concentrations in the nutrient solution.

Principles of nutrient solution calculation

To define the composition of a nutrient solution, target values for the following characteristics are needed:

1. Total ionic concentration (EC in $dS\ m^{-1}$)

2. pH

3. Macronutrient ratios (mM):
   - 3.1. K:Ca:Mg
   - 3.2. N:K
   - 3.3. $NH_4^+/(NH_4^+ + NO_3^-)$

or:

3. Macronutrient concentrations (mM):
   - 3.1. K, Ca, Mg
   - 3.2. NO_3^-,
   - 3.3. NH_4^+.

4. $H_2PO_4^-$ concentration (mM)

5. Micronutrient concentrations (mM)

Accession of a computer program that can be used to calculate nutrient solutions for soilless culture

www.ekk.aua.gr/excel/index_en.htm

The pH of nutrient solution

- **Desired values in the root environment: 5.5-6.5**

- **Acceptable range in the root environment: 5-7.**

- **To maintain the pH in the root zone in the desired range, the pH of the nutrient solution delivered to the crop should range between 5.5-5.8.**

- **This is attained by adding an acid (H^+), which reacts with the HCO_3^- contained in the irrigation water.**

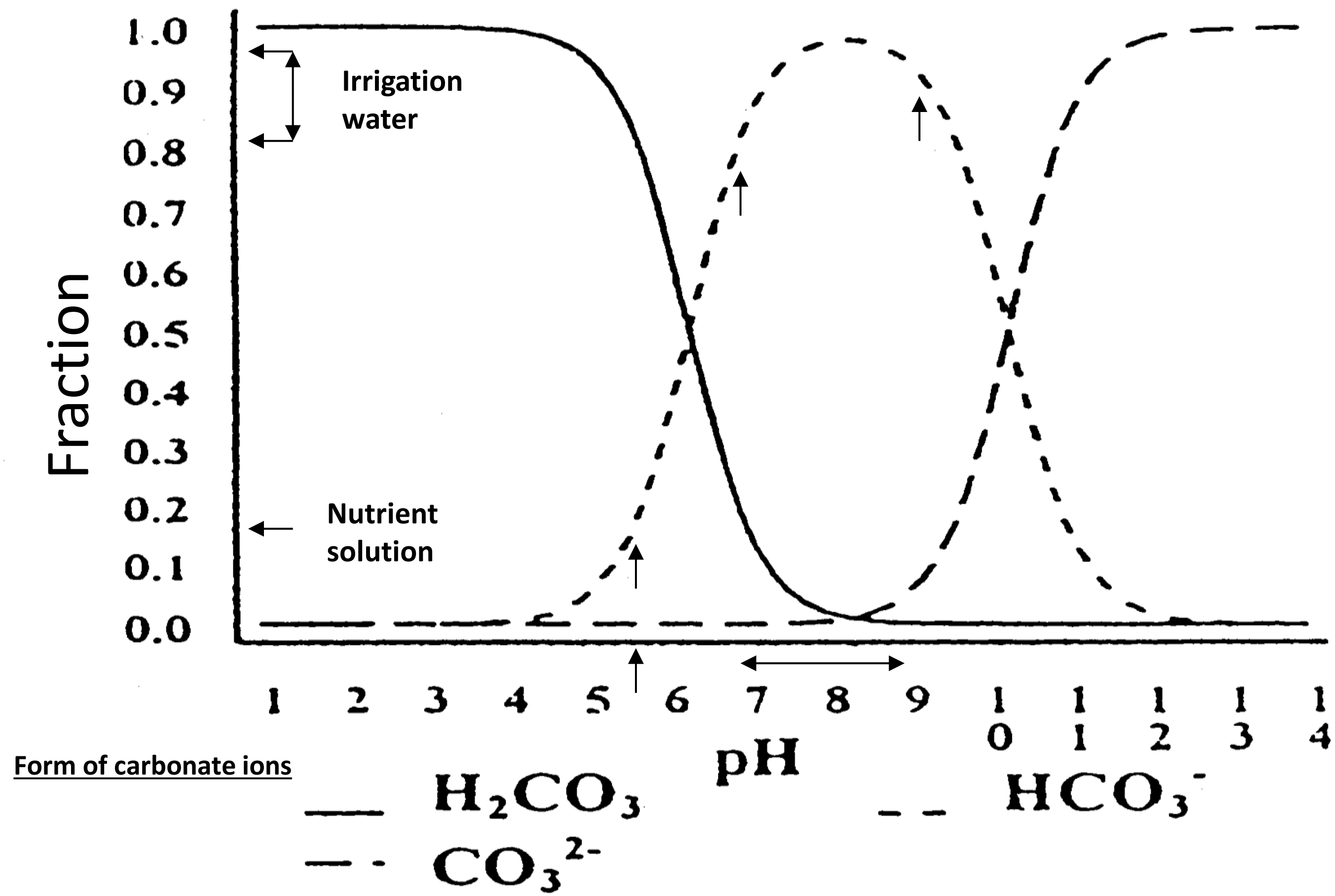
Reaction of HCO_3^- in water solutions

$$HCO_3^- + H^+ \leftrightarrow H_2CO_3 + H_2O \qquad K_{a1} = 10^{-6.3}$$

$$HCO_3^- + H_2O \leftrightarrow H^+ + CO_3^{2-} \quad K_{a2} = 10^{-10.3}$$

where K_{a1} και K_{a2} are the corresponding chemical equilibrium constants.

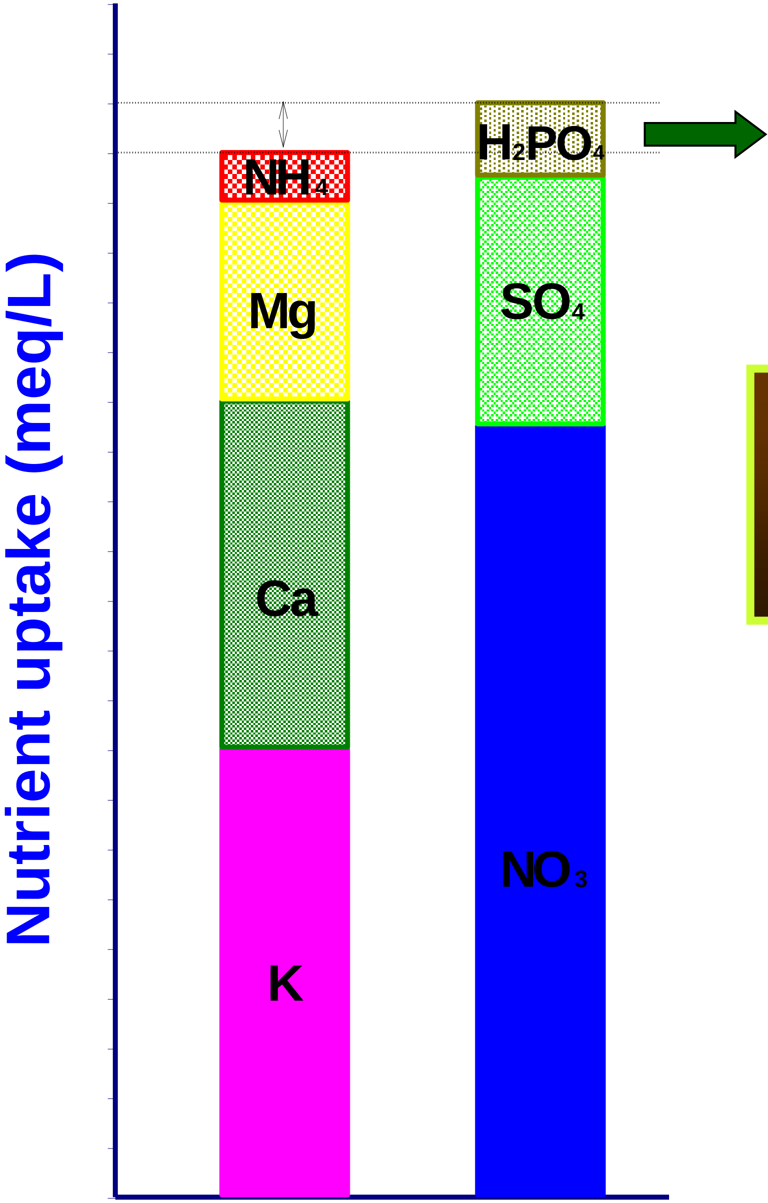
pH and HCO_3^-



Dissociation of carbonic acid in water

(De Rijck and Schrevens, J. Plant Nutr. 20, 1997)

Increase of pH due to cation to anion imbalance

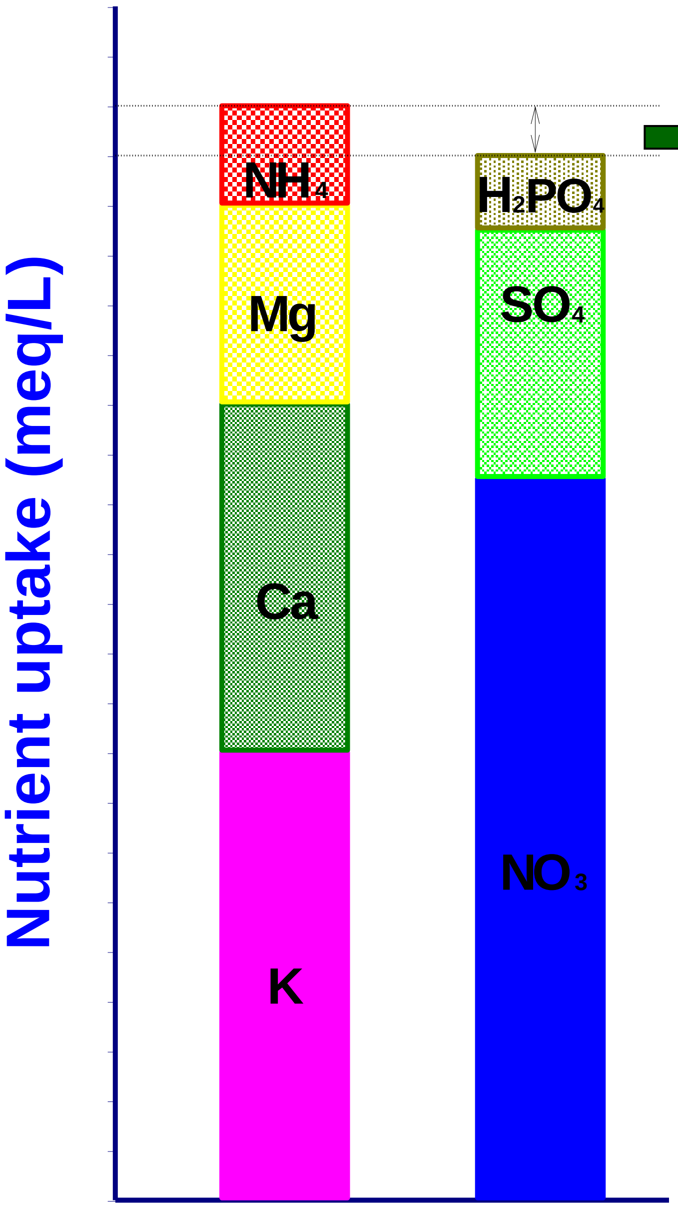


Anion uptake exceeds cation uptake

The charge difference in cytosol is electrochemically compensated for by excretion of HCO_3^- and/or OH^-

The pH in the external solution increases

Decrease of pH due to cation to anion imbalance



Cation uptake exceeds anion uptake

The charge difference in cytosol is electrochemically compensated for by excretion of H^+

The pH in the external solution decreases

Changes of pH in the root zone

Impact of nitrification

Nitrification of ammonium

Nitrosomonas sp.:

$$2NH_3 + 3O_2 \rightarrow 2NO_2^- + 2H^+ + 2H_2O$$

Nitrobacter sp.:

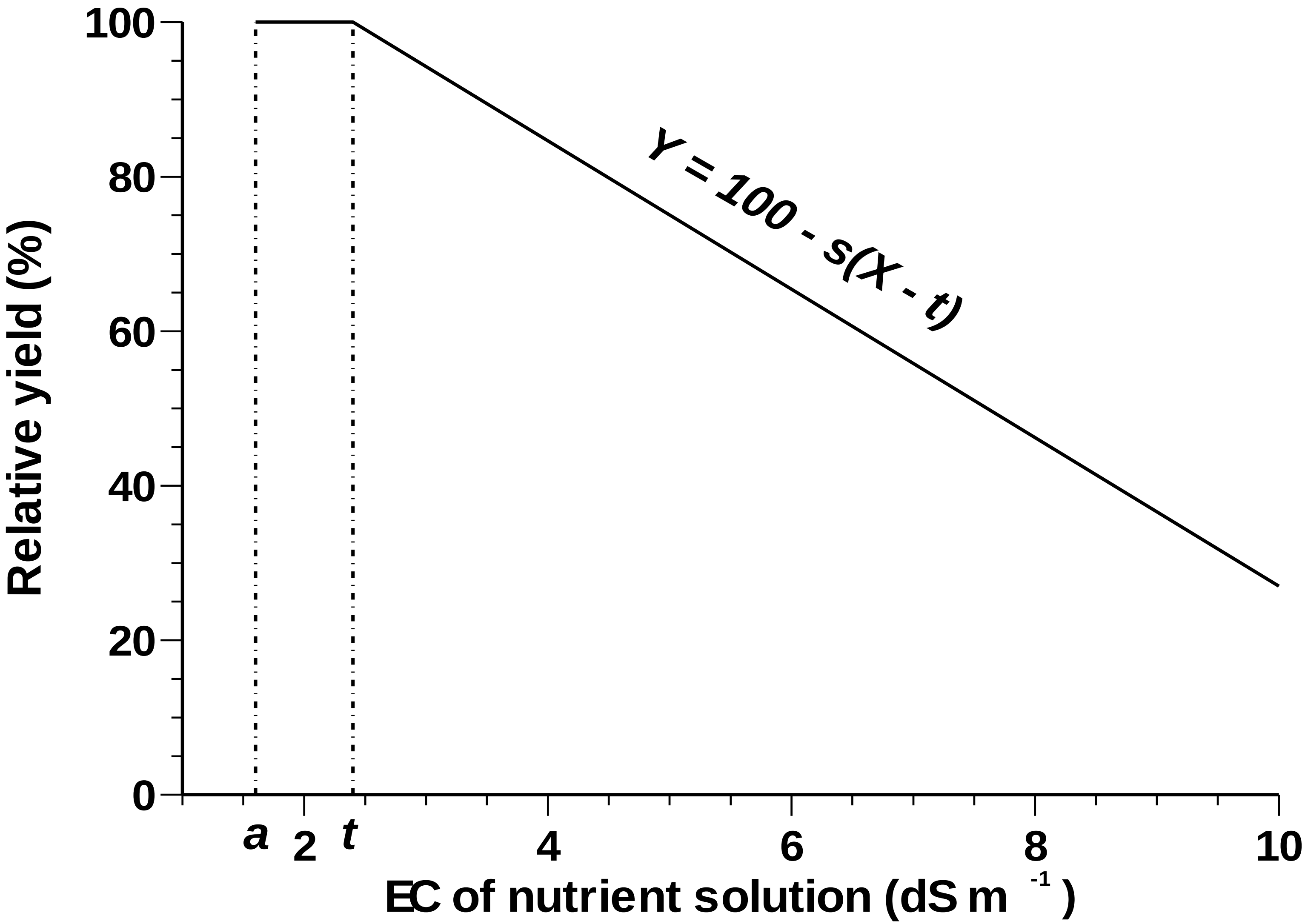
$$2NO_2^- + O_2 \rightarrow 2NO_3^-$$

Maintenance of pH within the desired range in the root zone

- Supply of irrigation solution with a pH ranging between 5.5 and 5.7.

- Part of nitrogen should be supplied in form of ammonium (N_r = 0.06 - 0.15)

Relationship between yield and total salt concentration in the root zone of soilless grown crops



(Savvas, 2001)

Control of EC in the root zone

- **Water of good quality (low NaCl, Ca, Mg, SO_4-S)**
- **Balanced composition of the supplied nutrient solution (EC, nutrient ratios)**
- **Proper irrigation scheduling (irrigation frequency in accordance with the energy input, i.e. solar radiation and heating)**
- **Irrigation water should not be used to wash out salts from substrates, unless it is rainwater.**

Irrigation management in soilless culture

- **Irrigation management includes water transport to the root zone and decision “when” to irrigate the crops and “how much” to apply.**
- **In soilless culture, the root zone volume is much smaller than in soil-based cropping systems and thus the total volume of available water per plant is smaller.**
- **Therefore “little and frequent” irrigation and fertilization is applied in soilless culture to maximize yield.**

Characteristics of irrigation systems

- **System capacity**

- **Uniformity** → $Q = 1 - \frac{\sum_{i=1}^{n} |x_i - A|}{nA}$

- **Storage capacity**

- **Pumping capacity**

Delivery systems:
1. Overhead systems

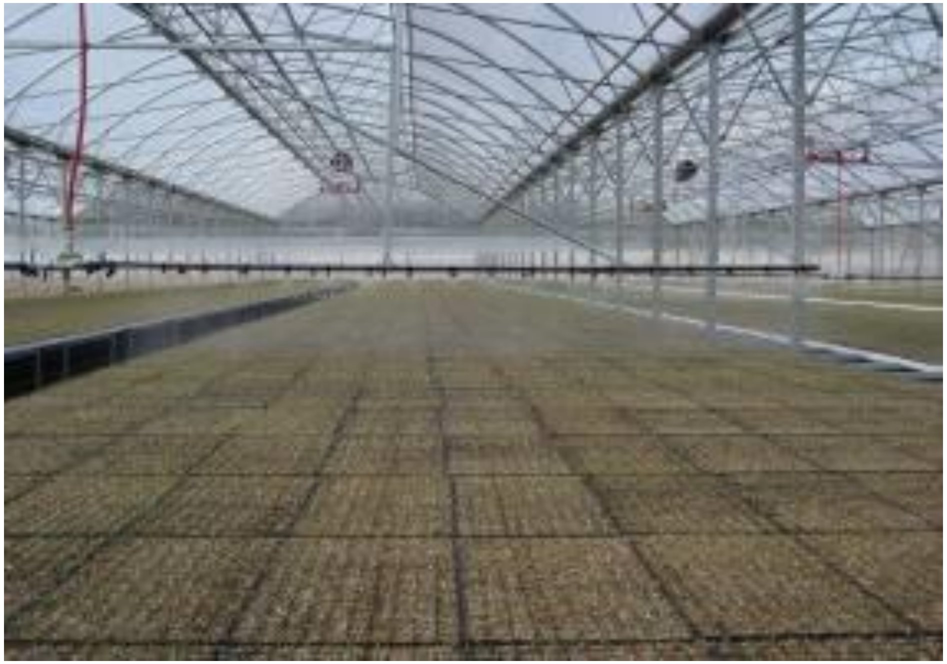


Table 15.6. Advantages and disadvantages of overhead systems

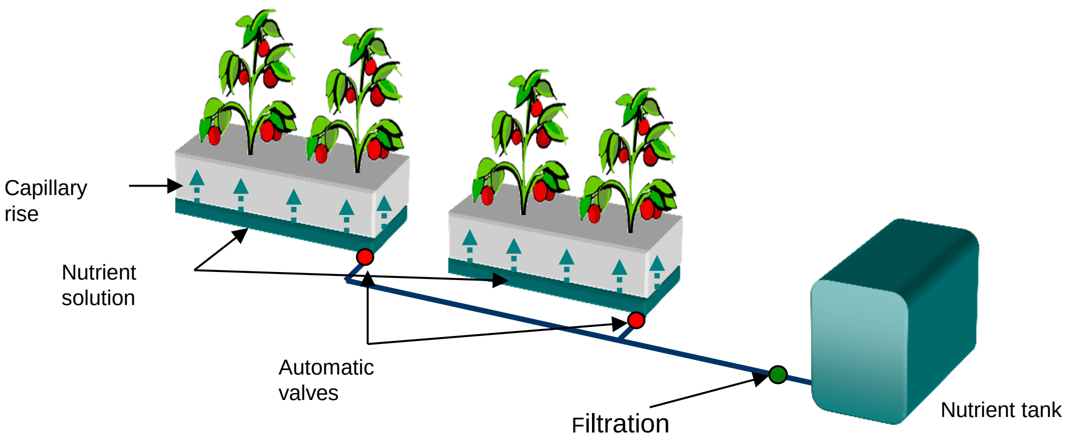
Advantages	**Disadvantages**
Relatively low installation cost	Waste of water due to unused run-off
Applicability in large areas	Disease incidence risk
Cooling effect	Residue risk on leaves and flowers
	Inefficient water use in substrate culture resulting in lower WUE
	Wetting the surrounding area of the plant

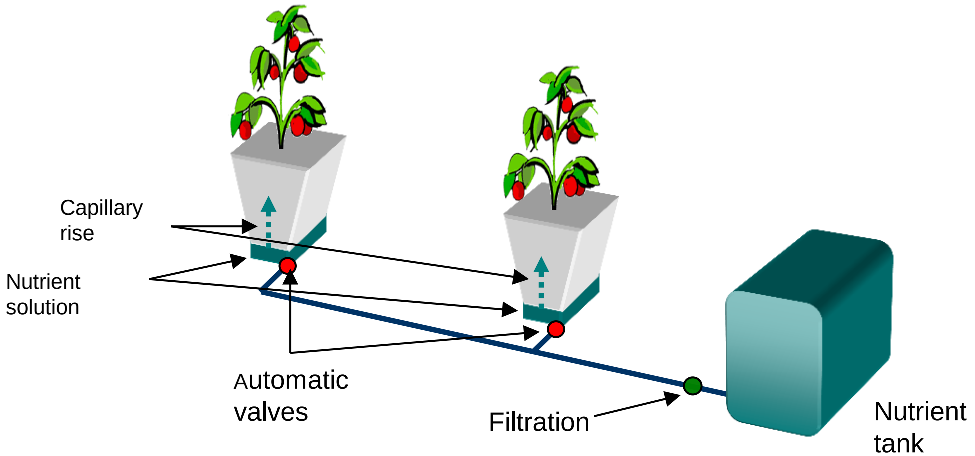
Delivery systems: 2. Drip irrigation

Table 15.7. Advantages and disadvantages of drip irrigation in soilless culture.

Advantages	**Disadvantages**
Irrigation of each plant individually	Emitter clogging
Efficient water use	Difficulty in evaluating system operation and application uniformity
Precise	Substrate/application rate interaction
Uniformity	Persistent maintenance requirements
Less run off	Smaller wetting pattern
Less evaporation	

Delivery systems: 3. Subirrigation





Subirrigation is superior in terms of water and fertilizer saving, uniformity of nutrition, labor efficiency and self-scheduling.

The root zone salinity is the most important disadvantage of subirrigation due to application of the nutrient solution from the bottom and its upward movement in the substrate

Irrigation scheduling approaches

- Substrate water status (Root zone sensors)
  - Substrate water potential
  - Substrate water content
- Plant water status
  - Tissue water status
  - Physiological responses
- Model-based estimation of water needs using real-time measurements of climatic parameters

Soilless cultivation of major greenhouse vegetable crops

A special nutrient solution composition for each crop species is recommended

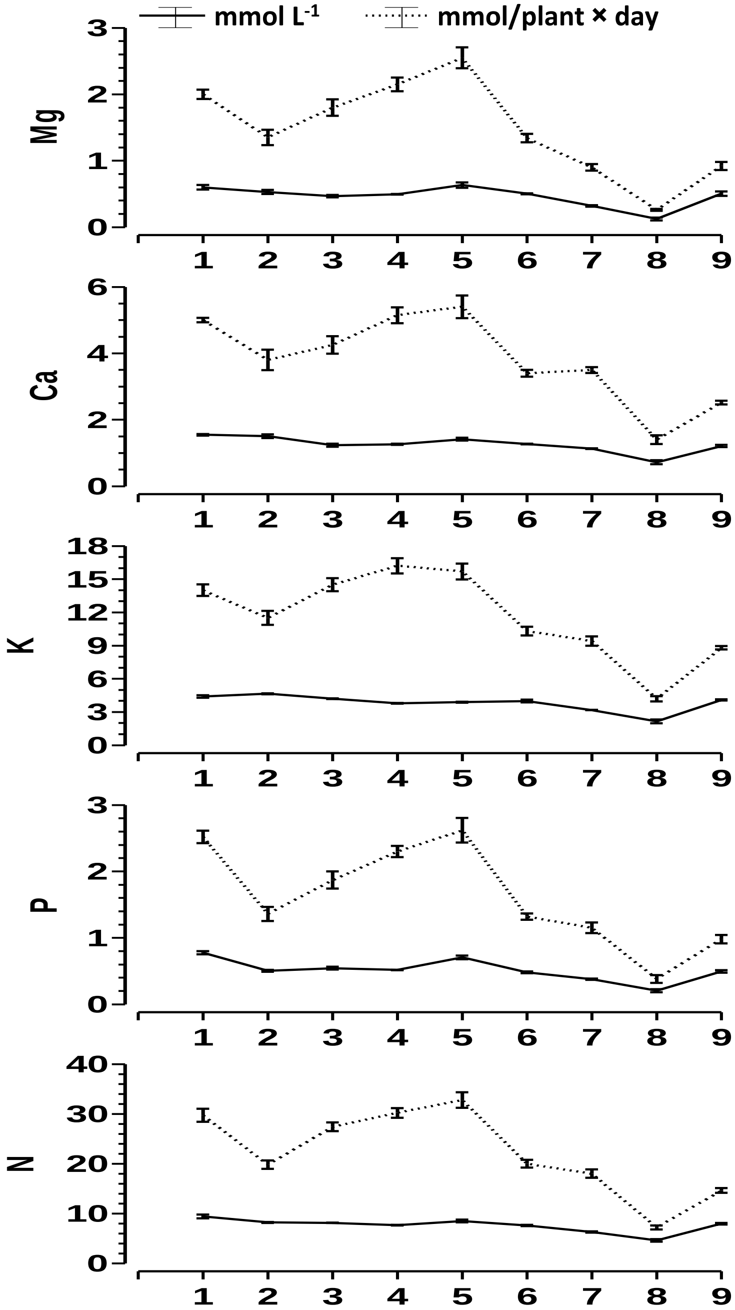
Table 15.11. Recommended EC (dS m^{-1}), pH and nutrient concentrations (mmol L^{-1}) in nutrient solutions (NS) for soilless tomato crops grown under Mediterranean climatic conditions (Savvas, 2012). The initially applied NS is that used to moisten the substrate or introduced to water culture systems before planting.

Desired characteristics	Initially applied NS	Vegetative stage			Reproductive stage		
		SSOS[1]	SSCS[2]	RE[3]	SSOS	SSCS	RE
EC	2.80	2.50	2.00	3.20	2.40	1.85	3.40
pH	5.60	5.60	-	5.80 – 6.70	5.60	-	5.80 – 6.70
[K^+]	6.80	7.00	6.40	7.50	8.00	7.50	8.20
[Ca^{2+}]	6.40	5.10	3.10	7.80	4.50	2.30	8.00
[Mg^{2+}]	3.00	2.40	1.50	3.40	2.10	1.10	3.40
[NH_4^+]	0.80	1.50	1.60	<0.60	1.20	1.40	<0.40
[SO_4^{2-}]	4.50	3.60	1.50	5.00	4.00	1.50	6.00
[NO_3^-]	15.50	14.30	12.40	18.00	12.40	11.00	17.20
[$H_2PO_4^-$]	1.40	1.50	1.30	1.00	1.50	1.20	1.00
[Fe]	20.0	15.00	15.00	25.00	15.00	15.00	25.00
[Mn]	12.00	10.00	10.00	8.00	10.00	10.00	8.00
[Zn]	6.00	5.00	4.00	7.00	5.00	4.00	7.00
[Cu]	0.80	0.80	0.80	0.80	0.70	0.70	0.80
[B]	40.00	35.00	20.00	50.00	30.00	20.00	50.00
[Mo]	0.50	0.50	0.50	-	0.50	0.50	-

[1]SSOS: solution supplied to open systems;

[2]SSCS solution supplied to closed systems;

[3]RE target concentrations in the root environment.



An example of uptake concentrations versus absolute nutrient needs per plant per day

Data originate from an eggplant crop grown hydroponically in a greenhouse.


Thank you for your attention!!