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FINAL REPORT ON AGRICULTURAL PRODUCTION UNDER GREENHOUSE CONDITIONS IN EUROPE, MEDITERRANEAN AREAS AND SOUTHEASTER SPAIN AND EXISTING LEGAL NORMATIVE

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Deliverable abstract

Agriculture in Europe is a very important sector, both economically and socially. In the last decades, water and fertilizers have increased their prices enormously and they are becoming for the farmers a necessary luxury that have to afford. In this sense, the production under greenhouse is emerging as a solution for the reduction of the use of water and fertilizer as comparing for the cultivation in open fields. Moreover, the recent use of the recirculation of drainages (greenhouse close systems vs open systems) is offering to the farmers the possibility to save a vast amount of money in both, fertilizers and water. This, together with the improvement in crops production and quality and the advantage that the recirculation of water and fertilizer offer to the environment, make this system a matter of study and research, with the objective to find the better methods to cope with it.

In this report we summarized some important information regarding the soilless production in Europe and more specifically in Southern Europe and Spain, the crops, production, and quality index for these regions, the amount of water and fertilizers used for these crops up to date, as well as the incidence of diseases and pests in these crops grown under greenhouse. We reviewed the economic and environmental aspects surrounding these type of cultivations, as well as the actual European legislation governing the main environmental policies. All these with the main objective of provide enough information that supports the use of close irrigation systems rather than the open systems, which are the most used and extended in the southern indoor agriculture.

List of Contents

1. Overview

Agriculture in Europe is a very important sector, both economically and socially. In the last decades, water and fertilizers have increased their prices enormously and they are becoming for the farmers a necessary luxury that have to afford. In this sense, the production under greenhouse is emerging as a solution for the reduction of the use of water and fertilizer as comparing for the cultivation in open fields. Moreover, the recent use of the recirculation of drainages (greenhouse close systems vs open systems) is offering to the farmers the possibility to save a vast amount of money in both, fertilizers and water. This, together with the improvement in crops production and quality and the advantage that the recirculation of water and fertilizer offer to the environment, make this system a matter of study and research, with the objective to find the better methods to cope with it.

In this report we summarized some important information regarding the soilless production in Europe and more specifically in Southern Europe and Spain, the crops, production, and quality index for these regions, the amount of water and fertilizers used for these crops up to date, as well as the incidence of diseases and pests in these crops grown under greenhouse. We reviewed the economic and environmental aspects surrounding these type of cultivations, as well as the actual European legislation governing the main environmental policies. All these with the main objective of provide enough information that supports the use of close irrigation systems rather than the open systems, which are the most used and extended in the southern indoor agriculture.

2 Assessment of soilless cultures in European countries

2.1 Crops soilless production

A very significant event in the world history of Agriculture is the domestication of plants by mankind. Instead of depending on wild growth, it was realized that the planting of seeds or cuttings allowed the propagation of the type of plants desired. Another important breakthrough resulted from the need to protect the domesticated plants from abiotic and biotic stress factors. Protected cultivation emerged as a way to protect crops from adverse weather conditions allowing year-round production and the application of an integrated crop production and protection management approach for better control over pests and diseases (http://www.fao.org/3/a-i3284e.pdf)

2.1.1 Europe

Greenhouse industry is widely extent in Europe. In the Mediterranean region, protected cultivation is expanded. It has estimated 220000 ha of greenhouses, 90 percent are covered with plastic and 10 percent with glass. The experience of greenhouse production, which emerged in northern Europe, stimulated development in other areas, including the Mediterranean, North America, Oceania, Asia and Africa, with various rates and degrees of success. It has been shown that a mere transposition of north European solutions to other parts of the world is not a valid process. Each environment requires further research, development, extension, training and new norms of application to meet local requirements.

The cultivation of plants in systems without soil in situ is defined in literature as "soilless culture" (Gruda, 2009). Many such systems are based on the use of solid rooting media for growing plants. They are usually called "growing media" or "substrates"; however, sometimes terms like "aggregate systems", "supporting media" or "potting soil" are used. With reference to plant cultivation and propagation, "growing media" or "substrates" are defined as all those solid materials, other than soil, which alone or in mixtures can guarantee better conditions than agricultural soil (for one or more aspects). Hence, media of different origin take on the role of soil and provide anchorage for the root system, supply water and nutrients for the plant, and guarantee adequate aeration in the root area (Gruda et al., 2006). Growing media are used in containers (organic substrates, perlite etc.). However, sometimes they are used in the form of prepared cubes (rockwool cubes for seedling and transplant production), bags and slabs (peat-based substrates and rockwool, respectively), mats (polyurethane foam) and troughs (rockwool); these last three are also used for vegetable production in soilless culture systems.

2.1.2 Spain

The area dedicated to greenhouses, has increased significantly in recent decades, from 546 ha in 1968 to 62.065 ha in 2013 (MAAMA, 2013). The largest concentration of greenhouses is located in the South and Southeast of Spanish peninsula (Andalusia and Murcia) and the Canary Islands.

In 2013 the greenhouses in Andalusia accounted for 71% of the surface of this culture system in Spain, highlighting Almeria with a representation of 48.5% compared to the national total area. In the communities of Canary Islands and Murcia, greenhouses occupy 11% in each one of them. The remaining 7% is mainly concentrated in the Valencian Community, Catalonia, Navarre and Galicia (MAAMA, 2013).

2.1.3 Murcia

Regarding Murcia, and considering the last decade from 2002 to 2008, the area of greenhouses increased, but from 2008 to 2013 a slight decline in the Region of Murcia is observed, decreasing from 2008 to 2013 in almost 2,500 ha (MAAMA, 2002, 2013).

With respect to the representation of the greenhouses in relation to cropland in 2013, in Spain account for only 0.4%, in Andalucía 1.3%, but 16.6% in the province of Almería; in the Canary Islands 15.8% and 1.4% in the Region of Murcia. In the southeast of the Iberian Peninsula, in the last decades, due especially to the increase in intensive agriculture using greenhouses, a remarkable transformation of the landscape occurred. It is certainly noteworthy Almería (Hernandez Porcel, 2005), this type of agriculture have been constituted as a landscape, being the greater European exponent model, and probably global (Tolon-Becerra and Bravo Lastra, 2010). In Europe, as in other continents, this model of agriculture and therefore, Almeria development, is known and envied (García Lorca, 1999). Started in the 1950s, is from 1977 when the phenomenon as "Almería miracle" started to described (García Lorca, 1999). But the province of Almeria has not been the only region that has undergone a transformation of the landscape as a result of the introduction of greenhouses. The Spanish Southeast has been characterized by a predominance of this activity, and this is the case of the Region of Murcia and the region of the field of Cartagena-Mar Menor (CCMM) here studied (Caballero Pedraza et al., 2015).

Data belonging to 2015, collected in the agricultural statistics provided by the Ministry of agriculture and water of the Region of Murcia, under the heading of “Regional Areas Greenhouse, Padding and Localized Irrigation (CARM, 2016)” report of the total area of crops in the greenhouse, padding and localized irrigation, distinguishing by types of farming:

	GREENHOUSE	PADDING	LOCALIZED IRRIGATION
Arable crops			
☐ **grain cereals**			11
☐ **forage crops**			1
☐ **industrial crops**		14	35
☐ **flowers**	55		64
☐ **vegetables**	1.249	2.604	16.480
☐ **leguminous grain**			
☐ **tubers human consumption**			3,870
Total arable crops	**1.304**	**2.618**	**20.461**
Woody crops			
☐ **Citrus**			
☐ **non-citrus fruit**			995
☐ **olive grove**			350
☐ **other woody crops**			188
☐ **vineyards**	5		39
☐ **nurseries**	75		98
☐ **Total woody crops**	**84**		**9.179**
☐ **Total all crops**	**1.388**	**2.618**	**29.640**

In terms of arable crops, it can be noted that they clearly dominated acreage on the different options, the cultivation of vegetables. Among them, notably the surface destined to melon (42 greenhouse, 2.160 in lay and 3.895 in localized irrigation), followed by cauliflower and Broccoli (476 in padding and 4.918 in localized irrigation), pepper (8.945 in greenhouse, 29 in padding and 1007 in localized irrigation) and lastly, tomato (79 in the greenhouse, and 111 in localized irrigation).

If the total data of the region of Murcia are taken into account, the following data are collected:

Table 2: total surface in the Region of Murcia's greenhouse, padding and localized irrigation crops.

	GREENHOUSE	PADDING	LOCALIZED IRRIGATION
Arable crops			
☐ grain cereals			11
☐ forage crops			1
☐ industrial crops		317	408
☐ flowers	186		267
☐ vegetables	3,700	12.909	16.480
☐ leguminous grain			
☐ tubers human consumption			4.440
Total arable crops	**3,886**	**13.226**	**45.696**
Woody crops			
☐ Citrus	27		30.565
☐ non-citrus fruit	103		25.903
☐ olive grove			6361
☐ other woody crops			215
☐ vineyards	898		13.546
☐ nurseries	164		359
☐ Total woody crops	**1,192**		**79.949**
☐ Total all crops	**5.078**	**13.226**	**122.645**

It could be seen as the total number of surfaces cultivated in the Region under greenhouse in arable crops, a 33.5% is located in the region of the field of Cartagena, in the same way, 19.8% of total crops in padding are in this region, as well as 44.8% of the crops with localized irrigation.

Regarding the total of crops of this kind in the Region of Murcia, 27.3% of the total crop in greenhouse is located in the Campo de Cartagena, as is the case with padding where a 19.8% is located in this region, as well as the 24.1% of the total of localized irrigation (CARM, 2016)

2.2 Species produced, production, quality of products and markets

Glasshouses are the most commonly found greenhouse structures in cold parts of Northern Hemisphere. In the Netherlands the average glasshouse area was 1.5 ha in 2003 (Bunschoten and Pierik, 2003). The glasshouse area in southern European is limited, mainly because of the high investment costs.

During the last 20 years countries in the Mediterranean climate area have become increasingly competitive producers of greenhouse vegetables. During this time there has been a revolution in greenhouse production technology in terms of greenhouse design, type and quality of the plastic covering material, fertigation, mulch, use of high-yielding hybrids and cultivars, plant training and pruning techniques, integrated pest management, the use of pollinator insects, climate control, soil solarization etc. Only a few years ago, a yield of 100 tons per hectare of tomato in a greenhouse was considered a good performance. Today, for growers in Mediterranean climate areas, a harvest of 300 tons per hectare is not unusual.

It is believed that greenhouse crop production is destined to play an increasingly important role in the Mediterranean climate environment as a means for sustainable crop intensification leading to optimization of water-use efficiency in an environment of water scarcity in addition to better control of product quality and safety, in line with the market demand, standards and regulations. The use of greenhouse and plastic house techniques has contributed significantly to the improvement of water-use efficiency. The plastic or glass cover creates a special microclimate (Abou Hadid and El-Beltagy, 1991) in which radiation and wind movement are lower but relative air humidity is higher than in the open field, favoring a reduction in evapotranspiration (Eissa et al., 1991). Furthermore, the higher temperature results in increased plant growth rate and higher yield per unit area of cultivated land. Increase in yield and reduction in water consumption under protected cultivation was reported by Abou Hadid et al. (1992). Protected cultivation produces higher yields with less water: water-use efficiency is improved (Abou Hadid and El Beltagy, 1992). The efficient use of water in greenhouses is also reflected in the efficient use of fertilizers (Medany et al., 1997). Many reports on this subject (Ismail et al., 1996; El-Behairy et al., 1996; Abd Elmoniem et al., 1996) indicate that in plastic houses protected cultivation and soilless culture techniques improve the nutritional conditions and nutritional problems not easily solved under open field conditions.

The most commonly grown species in greenhouses are vegetables with medium thermal requirements: tomato, pepper, cucumber, melon, watermelon, marrow, green bean, eggplant. For example, In Italy, cherry and cluster tomatoes were quite rare 20 years ago and now represent more than 50 percent of greenhouse production

TABLE 1
Major cropping cycles and the vegetable species grown in Mediterranean greenhouses in Almería, SE Spain

Major cycles	Typical period of cycle	Crops grown
Autumn–spring	August–May	Tomato, eggplant
Summer/autumn–winter	July/Aug./Sept.–Jan./Feb.	Pepper, tomato, cucumber, zucchini
Spring–summer	Jan./Feb./Mar.–May/June	Melon,[a] watermelon,[a] tomato, cucumber, zucchini

[a] Cooling with whitewash not used during warm periods with these species.

2.3 Culture practice

Soilless culture represents one of the main solutions for soil problems, have positive effects on the environment and improve fertilizer and water-use efficiency. This is especially the case in Mediterranean countries where shortage of good quality water is a major constraint in protected cultivation. At present, a relatively small proportion (approximately 10%) of growing media, which are very important for a good start to plant cultivation, can be used for the production of seedlings and transplants.

Besides supplying the local markets, the production of greenhouse vegetables is greatly valued for its export potential and plays an important role in the foreign trade balance of several national economies in the Mediterranean region. However, the intensification of greenhouse crop production has created favorable conditions for many devastating pests and diseases.

GRUDA ET AL., 2006

Plate 3

Materials used as growing media

From left to right and top to bottom: rockwool, polyurethane foam, expanded shale, volcanic material, open porous clay granulate, expanded clay, perlite, black peat, coarse wood fibre, fine wood fibre, vermiculite, and light peat

Choosing a substrate

Desirable properties:

- Low volume weight
- Good reserve of easily available water and good aeration
- Good rehydration properties after drying
- Stable structure
- Good buffering capacity for an optimal pH
- Appropriate pH properties for the crop
- Uniform from batch to batch
- Free of phytotoxic compounds
- Low micro-organism activity
- Pest- and pathogen-free

Aspects to be considered:

- Availability of information on chemical and physical characteristics
- Type of soilless system adopted
- Shape and volume of the container
- Reusability
- Costs

This has significantly increased the need for pesticide applications. At the same time, legislative measures and standards requirements regarding the quality and safety of vegetables have become increasingly demanding. Consumer awareness has risen and the demand for pesticide-free products is a reality which cannot be ignored.

TABLE 1

Water soluble fertilizers commonly used in soilless culture

Fertilizer	Chemical formula	Percentage in nutrient	Molecular weight (g)	Solubility (kg litre^{-1}, 0 °C)
Ammonium nitrate	NH_4NO_3	N: 35	80.0	1.18
Calcium nitrate	$5[Ca(NO_3)_2 \cdot 2H_2O]$ NH_4NO_3	N: 15.5, Ca: 19	1 080.5	1.02
Potassium nitrate	KNO_3	N: 13, K: 38	101.1	0.13
Magnesium nitrate	$Mg(NO_3)_2 \cdot 6H_2O$	N: 11, Mg: 9	256.3	2.79 (20 °C)
Nitric acid	HNO_3	N: 22	63.0	-
Monoammonium phosphate	$NH_4H_2PO_4$	N: 12, P: 27	115.0	0.23
Monopotassium phosphate	KH_2PO_4	P: 23, K: 28	136.1	1.67
Phosphoric acid	H_3PO_4	P: 32	98.0	-
Potassium sulphate	K_2SO_4	K: 45, S: 18	174.3	0.12
Magnesium sulphate	$MgSO_4 \cdot 7H_2O$	Mg: 9.7, S: 13	246.3	0.26
Potassium bicarbonate	$KHCO_3$	K: 39	100.1	1.12
Iron chelates	various types	Fe: 6–13	-	-
Manganese sulphate	$MnSO_4 \cdot H_2O$	Mn: 32	169.0	1.05
Zinc sulphate	$ZnSO_4 \cdot 7H_2O$	Zn: 23	287.5	0.62
Copper sulphate	$CuSO_4 \cdot 5H_2O$	Cu: 25	249.7	0.32
Borax	$Na_2B_4O_7 \cdot 10H_2O$	B: 11	381.2	0.016
Boric acid	H_3BO_3	B: 17.5	61.8	0.050
Sodium octaborate	$Na_2B_8O_{13} \cdot 4H_2O$	B: 20.5	412.4	0.045
Ammonium heptamolybdate	$(NH_4)_6Mo_7O_{24}$	Mo: 58	1 163.3	0.43
Sodium molybdate	$Na_2MoO_4 \cdot 2H_2O$	Mo: 40	241.9	0.56

A remarkable example of the efficient use of water resources is the use of substrates in soilless culture for better vegetable quality and as a means for improving water use efficiency. To clarify the relationship between substrate culture and water-use efficiency, it should be noted that: field-grown tomato produces 3 kg/m3 of water; plastic house soil-grown tomato produces 17 kg/m3. Soilless culture techniques were developed under glasshouses in order to overcome major agricultural problems, including nutrition, plant diseases and environmental pollution. It was later discovered to be an efficient water-saving tool. The development of a simple low-cost hydroponic system was the main challenge to enable soilless culture. Several attempts to design and implement soilless culture techniques were made and proved to be economically viable and environmentally safe. Water-use efficiency was thus greatly improved and the chemicals used for nutrition and pest and disease control reduced to a very low level. Production costs are relatively high but future research looks to reducing costs and improving applicability on a large scale in arid lands.

Cultural practices applied

The Mediterranean region is one of the most important areas in the world in terms of protected cultivation, thanks to its mild winter climatic conditions and the possibility of adopting very simple protective shelters. Vegetable production under protected cultivation is a major agricultural sector in most Mediterranean countries and both cultivated area and production have increased consistently in recent decades. Solanaceous crops (tomato, pepper, eggplant) and cucurbits (cucumber, melon, courgettes, watermelon) now account for more than 80 percent of the protected area (Tuzel and Leonardi, 2010).

There are a wide range of cultural practices of varying importance, but with the common objective of optimizing production value and maximizing economic returns from vegetable production. Most are associated with integrated pest and disease management, particularly in terms of reduction of pesticide use. Some cultural practices – namely plant protection, irrigation and fertilization – are described in detail in separate chapters. The current chapter focuses on cultural practices related to soil preparation, crop establishment, control of growth and fruit-setting during the cropping period, intercropping, mulching and harvesting. High yields and good quality of high value greenhouse vegetables can be achieved with correct soil management and attention to the following practices:

- Increase of organic matter content to improve soil texture and related characteristics, soil chemical properties and cation exchange capacity.
- Control of salinity and alkalinity.
- Provision of adequate and balanced nutrient supply.
- Control of soil-borne pathogens.
- Plan the production season based on market analysis.
- Pay attention to soil management for high yield, high quality and high value:
  - Perform as little tillage as possible.
  - Maintain or restore soil organic content by manure or compost application.
  - Analyze soil and organic manure (or compost) to prevent contamination; apply adequate and balanced nutrients at appropriate times and in appropriate doses.
  - Control salinity by irrigating with small volumes, by tillage and by mulching to prevent upward movement of saline water from the deeper layers.
  - Control soil-borne pathogens by avoiding the application of chemical treatments for soil disinfection whenever possible.
- Adopt soil solarization – a non-chemical method to combat soil-borne pathogens:
  - Apply in the summer months (June, July, August).
  - Irrigate soil before and during solarization if it becomes dry.
  - Place transparent PE (25–30 µm) over the soil surface; bury the edges without gaps.

- Leave plastic in place for 4–6 weeks.

• Use correct plant spacing:

- Avoid too high density to prevent disease incidence.

- Keep density lower in long-cycle crops than in short-cycle crops.

• Adopt timely and correct pruning techniques; remove all waste material to prevent new infection or the spread of pest and diseases.

• Use bumblebees for pollination:

- Place hives 0.5–1 m above the ground.

- Protect hives against sun and condensation of water.

- Avoid ants or other insects entering hives.

• Adopt site-appropriate mulching for efficient management at different sites, with different soils, crops and climatic conditions.

• Handle harvested fruit carefully to avoid damage, especially bruising. For each crop, take account of distinct quality standards for the classification (size, colour), tolerances, definitions (i.e. well-developed or damaged) and classification of defects.

TABLE 1

Cultivation schedule and yield of several crops in different locations of the Mediterranean region and in the Netherlands

	Transplanting	Harvest start	Harvest end	Yield (kg/m^2)
Almeria [a]				
Truss tomato	Aug.	Nov.	June	15
Pepper	July	Oct.	Mar.	7
Cucumber (several cycles)	Aug.–Oct.	Oct.–Dec.	Dec.–Mar.	6–10
Ragusa [b]				
Cherry tomato	Sept.	Nov.	June	6–12
Truss tomato	Oct.	Dec.	April	8–10
Pepper	July	Sept.	Dec.	4–5
	Oct.	Mar.	April	4–6
	Nov.	April	June	6–9
Netherlands [c]	*(no. weeks)*	*(no. weeks +/- 2)*	*(no. weeks, incl.)*	
Round tomato	48–50	12	47–50	60
Beef tomato	47–50	12	46–50	60
Truss tomato	47–50	12	47–52 interplant	55
Cherry tomato	48	12	46	32
Red pepper	47–52	12	43–44	26
Green pepper	1–3	12	47–49	32
Yellow pepper	48–53	15	45–50	28
Orange pepper	47–48	12	44–45	25
Cucumber (3 crops/year)	1–2, 23–24, 33–34	7, 26, 36	23, 33, 47	81

[a] Cajamar Foundation.
[b] C. Leonardi (personal communication).
[c] Quantitative information for the Dutch Glasshouse Horticulture 2008–09. Ed. P.C.M. Vermeulen. Wageningen UR Greenhouse Horticulture, Bleiswijk, Report No. 185.

2.4 Incidence of diseases and pests,

Pest management

Greenhouse management for the control of insects and diseases depends on: the local climate; external disease and insect pressure; the greenhouse structural design;

availability of climate control equipment; and the skill level of the greenhouse workers.Vegetable diseases include early blight, late blight, powdery mildew, downy mildew, damping-off, and viral and bacterial diseases. For effective control, they must be properly identified. An integrated approach to disease management involves the use of resistant cultivars, sanitation, sound cultural practices and the proper use of the correct pesticides.

Fungicides are potentially very effective with some diseases, but may be ineffective with others (Table 1):

• Root diseases: apply broad-spectrum fungicides as a drench on a preventive basis, read directions on the pesticide labels, and note that an additional application of water may be necessary.

• Foliage diseases: obtain thorough spray coverage, and treat when disease is first evident.

TABLE 1

Selected fungicides and bactericides labelled for vegetable plants

Fungicide	Targeted pest	Labelled crops	Comments
Basic copper sulphate (Cuprofix Ultra 40 D Disperss), 12 hr REI, Group M1	Many diseases incl. angular leaf spot, downy mildew, Alternaria blight, anthracnose, bacterial blight, bacterial spot (depending on crop)	Many incl. cucumbers, eggplant, peppers, tomatoes	Crops grown in greenhouse may be more sensitive to copper injury so the user should determine plant sensitivity. Observe for 7–10 days for symptoms of injury.
Bacillus pumilus (Sonata), 4 hr REI, Group 44, OMRI listed	Downy mildew, powdery mildew	Many incl. cole crops, curcurbits, fruiting, leafy vegetables	Begin applications when greenhouse conditions favour disease development.
Bacillus subtilus (Serenade), 4 hr REI, Group 44, OMRI listed	Many diseases incl. downy mildew, powdery mildew, bacterial spot, early blight	Many vegetables incl. broccoli, leafy vegetables, cucurbits, peppers, tomatoes	Preventive biofungicide. Thorough coverage essential.
Bacillus subtilis (Cease), 4 hr REI, Group 44, OMRI listed	Many diseases incl. leaf spots, powdery mildew, botrytis blight, downy mildew	Many incl. cole crops, curcurbits, fruiting vegetables, leafy vegetables,	Begin applications when greenhouse conditions favour disease development. Thorough coverage essential.
Copper Hydroxide (Champ DP Dry Prill, Champ Formula 2 Flowable, Champion WP, Champ WG [OMRI listed], Kocide 101, Kocide 2000, Kocide 4.5LF, Kocide DF), 24 hr REI, Group M1	Leaf spots, *Anthracnose*, bacterial spots and other diseases (see label)	See labels for specific crops	See labels for specific usage instructions.
Copper salts of fatty and rosin acids (Camelot), 12 hr REI, Group M1	Many incl. bacterial leaf spots, leaf spots and blights, downy mildew, powdery mildew	Greenhouse vegetables (see label for specific crops)	See label for specific usage instructions.
Cuprous oxide (Nordox 75 WG), 24 hr REI, Group M1	*Anthracnose*, *Phomopsis*, *Botrytis*, various leaf spots and blights (see label)	Tomatoes, peppers, eggplant	Begin applications when disease first threatens.
Dichloran (Botran 75-W), 12 hr REI, Group 14	*Botrytis*, white mould (*Sclerotinia*)	Cucumbers, leaf lettuce, tomatoes	Seedlings or newly set transplants of tomatoes may be injured by drenching.
Fenhexamid (Decree 50WDG), 12 hr REI, Group 17	*Botrytis*	Fruiting vegetables, tomatoes, cucumber, leafy greens (except spinach)	Thorough coverage needed. Do not make more than two consecutive applications. Do not apply in the field.
Horticultural oil, paraffinic oil (Ultra-Pure Oil), 4 hr REI, NC Saf-T-Side, spray oil emulsion fungicide, insecticide and miticide), 12 hr REI, NC, OMRI listed (Organic JMS Stylet Oil)	Powdery mildew	Cucurbits, melons, squash and others	Contact fungicide. Application should be made when disease is first noticed. See label for information on plant safety. Use lower label rates in the greenhouse. Applications should be preceded by a phytotoxicity check to ensure that material is safe.
Hydrogen dioxide (Oxidate), 0 hr REI (non-spray), 1 hr REI (spray), OMRI listed	Many incl. mildews, leaf spots and blights, and root	Tomatoes, peppers, leafy and cole crops, cucurbits and others	Strong oxidizing agent. Contact, oxidizing sanitizer.

Table 2 represents the most common viral diseases of the main vegetables grown in EU:

TABLE 2
Main viral diseases of vegetable crops by host and means of transmission

	Crop		
Transmission	Tomato	Pepper	Cucumber
Seed-borne	TMV	TMV	CGMMV
Mechanical	TMV	TMV	CGMMV
Aphids	CMV, PVY	CMV, PVY	CMV, ZYMV
Whiteflies	TYLCV	-	CVYV, CYCDV
Thrips	TSWV	TSWV	

General pest management

Monitoring

Regular monitoring is the basis of all pest management programs. A regular, weekly scouting program should be conducted to detect problems at an early stage. Early detection and treatment lead to better pest control, since plant canopies are smaller and better spray coverage can be achieved.

Blue and yellow sticky cards

Use blue sticky cards to trap and detect adult stages of trips and use yellow sticky cards for whiteflies and microlepidoptera. Place one to four cards per 100 m2. The cards should be spaced equally throughout the greenhouse in a grid pattern with additional cards located near doorways and vents. Place some cards just above the plant canopy (to detect trips and whiteflies). Inspect and replace the cards weekly to keep track of population trends.

Plant inspection

Plant inspection is needed to assess general plant health and to detect diseases, mites and aphids, plus any hot spots of immature whiteflies. Randomly select plants at ten locations in an area of 100 m^2, examining plants on each side of the aisle. Begin in a slightly different location each week, walking through the greenhouse in a zigzag pattern down the walkway. Examine the underside of leaves for insect pests and inspect root systems to determine whether they are healthy.

Key plants and indicator plants

Focus on scouting key plants and indicator plants:

• Key plants are plants or cultivars with serious, persistent problems every year. For example, peppers, tomatoes and eggplants are prone to aphid infestations: look for aphids on young leaves and for shiny honeydew on the upper leaf surface. If grown near flowering plants, peppers, tomatoes and eggplant will have signs of an early trips population: look for distorted, young leaves with silvery flecked scars – signs of trips feeding damage.

• Indicator plants are used to detect the presence of pests. For example, faba beans (*Vicia faba* L.) and certain petunia cultivars can detect the presence of trips carrying TSWV. These plants will develop viral symptoms within one week if fed on by the infected trips. The petunia cultivar 'Summer Madness' and several varieties of faba bean have been successfully used to detect tospoviruses.

Record-keeping and decision-making

Each time the crop is scouted, record the pest numbers, their location and the number of plants inspected. Records of pest numbers and locations will help identify population trends. Population trends are an indication of whether initial control measures were successful or need to be repeated. Once this information is collected each week, a pest management decision can be made. Monitoring and record-keeping help make the necessary treatment decisions by providing answers to the following questions:

• Is the population decreasing, increasing or stable over the growing season?

• Is spraying required?

• Are insects migrating from weeds under the benches to the crops?

• Is the previous week's treatment working?

Biological control for insects and mites

Biological control is an option for aphids, mites, fungus gnats, thrips, whiteflies and some lepidopters. Natural enemies are living organisms. They do not act as quickly as pesticides so cannot be used as "rescue" treatment. Natural enemies (parasitoids, predators of pathogens) are best used early in the cropping cycle when plants are small, pest numbers are low and damage is not yet observed. A detailed plan of action is needed to ensure success. Accurately identify the key pests in the production system. Natural enemies, especially parasites, are often specific to a particular pest. Many insecticide residues can adversely affect natural enemies for up to 3 months after application.

2.5 Results from research projects on production under soilless greenhouse

Open systems versus closed systems

In Mediterranean countries, soilless cultivation has been developed mainly as open system, where excess nutrient solution is required to drain the substrate. In this kind of system, the irrigation strategy provides a quantity of nutrient solution that is 30 to 50 percent in excess of the crop requirements in order to avoid salt buildup near the root zone (Ehret et al., 2001).

In open-loop systems the water and nutrients are supplied as for a conventional on-soil crop and the drained nutrient solution is thrown out of the system. The leachate may be collected and reused to fertilize on-soil crops, but in most cases it is lost causing harm to the environment. Open-loop systems determine the nutrient solution to supply in conjunction with leaching, i.e. the volumetric ratio of the leachate to the applied nutrient solution. In closed-loop systems the drained nutrient solution is recovered, replenished and recycled. Compared with the open-loop system, it requires more precise a and frequent control of the nutrient solution; technical know-how is needed, as it is more sensitive to operational mistakes, in particular during spring due to the possible increase of nutrient concentration in the solution with increasing temperature and solar radiation. The returned nutrient solution has to be treated to restore its original nutrient element composition and to remove any foreign substances. Moreover, spreading of root-borne diseases may occur, thus sterilization of the solution must be provided to kill pathogens.

In closed systems, the nutrient concentrations in the solution supplied to the crop are largely determined by the composition of the recycled drainage solution. However, it changes during the cropping period and hence its composition is unknown. The changes in the nutrient concentration of the drainage solution complicate its recycling, because the amounts of nutrients needed to establish the target concentrations in the solution supplied to the plants are uncertain. The problem is further complicated by the fact that in commercial horticulture the replenishment process must be performed automatically. To overcome this problem, various automation techniques involving measurements of drainage solution characteristics and adjustments in real time are used in modern closed cycle soilless culture systems. A standard technique involves mixing of drainage and water at an automatically adjustable ratio by aiming at a preset EC in the outgoing mixture. This operation enables the maintenance of a constant, desired EC in the nutrient solution supplied to the crop by dispensing nutrients at standard injection rates to the mixture of drainage solution and water, despite any fluctuations in the composition of the drainage solution. Another approach is the injection of fertilizers into water at standard rates aimed at a preset EC and the subsequent mixing of the obtained solution with the effluents to be recycled. Also in the latter case, the mixing process is automatically adjusted in real time to a ratio resulting in a constant target EC in the outgoing irrigation solution. As stated above, both techniques are based on the injection of nutrients at standard rates, which are adjustable by the grower when the drainage solution is mixed with fertilizers and water prior to its resupply to the crop. If, for a particular crop species, experimentally established estimates of the mean uptake concentrations are known for all nutrients to be added in the nutrient solution, the rates of nutrient injection may be adjusted to equal levels with the anticipated uptake concentrations. Thus, as long as the system is closed, the rate of nutrient and water input into the closed system is equal to the rate of their removal due to plant uptake. Consequently, the supply of nutrients is adequate for optimal plant growth, but not excessive, and thus neither depletion nor accumulation of nutrients occurs in the closed system. Unfortunately, nutrient solution compositions corresponding to anticipated mean uptake concentrations, which can be used for balanced crop nutrition in closed soilless culture systems, are currently available only for the climatic conditions of the Netherlands (De Kreij *et al*., 1999). Hence, to optimize nutrient recycling in soilless culture in the Mediterranean region, there is a need to establish and validate estimates of the mean uptake concentrations for all nutrients under the specific climatic conditions. Long-term recycling of leachate solution may result in accumulation of sparingly absorbed ions, such as Na+ and Cl-. In order to ensure an adequate nutrient supply in closed soilless cultivations when the Na+ and Cl- levels in the irrigation water are not low, it is important to monitor salt concentrations in the drainage solution so as to assess their contribution to the total EC in the outgoing nutrient solution, which can then be adjusted in real time to a value that would ensure a constant nutrient supply to the crop. However, reliable tools providing real-time monitoring of specific ion levels in the drainage solution are currently not available at prices affordable to the growers. Therefore, the standard practice for coping with salt accumulation in closed systems is currently the provisional suspension of recycling and the discharge of the drainage solution until its EC returns to acceptable levels.

3 Environmental and directives

3.1 Aspects economic and environmental

Hydroponics in Spain

In Spain, the technological innovations made possible the expansion of protected crops to the coast of Murcia and Almeria. Until then, strong winds, poor soils and the scarcity of rain, had slowed the agricultural development of the area.

Thus, the emergence of greenhouses and new irrigation equipment adapted to the characteristics of the area allowed this development. Since then new technological advances have been incorporating that have allowed to continue economically viable agricultural production by increasing production.

However, the soil worked under greenhouse has suffered a progressive exhaustion due to its continued use, the presence of soil diseases (Fusarium, nematodes, etc), salinization etc. As a result, their original qualities have been deteriorating strongly, decreasing crop yields. This forced to adopt other solutions, and then Hydroponic systems were introduced as an alternative to the ground. These systems solved this problem successfully allowing to start the crop with total guarantee.

In the last decade, the surface of hydroponic has progressively increased in all provinces. We have gone from the 33 has in 1986 to more than 3000 in 2000, distributed mainly in Almeria, Murcia, Granada and the Canary Islands. It is obvious that practically all of these crops are protected, allowing greater control.

Hort species better suited to be grown in hydroponic are vegetables: tomato, cucumber, melon, pepper, Jewish, eggplant, watermelon, Zucchini and cut flowers.

There are different available commercial substrates and that have adapted perfectly to the agroclimatic conditions of different areas of culture.

The reasons to adopt hydorponic cultures are not only as a mere substitute for the degraded soil, but many others such as:

-Greater efficiency in the use of water and fertilizer.

-Reduction of cultural-intensive production without the need for crop rotations.

-Smaller and easier sterilization of the culture medium. Experience shows that this type of cultivation shows performance improvements as well as a greater homogeneity by reducing the amount of by-products.

This is because the plant finds what it needs (water, nutrients, oxygen,...) in optimal conditions and takes it with remarkable energy savings. This means that a higher percentage of carbohydrates is intended for productive purposes. The high level of technology that is incorporated in the farms of new construction, to control the various environmental parameters, make these systems play a very important role since it allows to control very well the conditions of the crop in the root zone, thus obtaining maximum performance.

In terms of the efficiency of the irrigated land in the Region of Murcia, the recorded from the CARM publications show us that this has resulted in a considerable increase in regards to the modernization of irrigation systems, power consumption. Thus, the average consumption of all irrigation is:

-in Spain: 0.3 kWh/m3
-in the Region of Murcia: 0, 3-0, 7 kWh/m3 (since 84% are pressurized irrigation)

The saving strategies followed have been:

- Localized irrigation
- Controlled deficit irrigation
- Fertigation
- Woody crops under mesh (citrus, fruit trees, vineyards)
- Greenhouses high technification: trigeneration
- Padded horticultural crops (biodegradable plastics)
- Padded with black screens in fruit tree soil
- Employment of very early varieties
- Pickup in the spring crop
- Automation communities of irrigators
- Irrigation automation
- Hydroponics
- Pseudohidroponia in Woody
- Regenerative techniques of the root system
- Employment of intensive Woody plantations with enanizantes patterns.

So the approach to improve the efficiency of irrigation, is proposed with the following challenges for the future:

- Reduction of water consumption strategies
- Strategies for reduction of energy consumption
  Necessary r & d on new filtration systems and irrigation, that decrease energy consumption.
- Recovery, regeneration and reuse of drainage:
  To minimize water loss by percolation deep and prevent the pollution of groundwater.

(García Lidón, a. 2014 2nd MEDITERRANEAN WATER FORUM III Dutch-Spanish Water Event technical workshop: efficient use of water in agriculture.)

As regards the profitability of crops under cover it has been found that all production systems under greenhouse, mesh or padded covers are under intensive irrigation systems.
According to the Ministry of agriculture, fisheries and food, for the year 2003, valued that irrigated acres produced six times more than in dryland and generated an income four times higher. (Morales Gil, A.; Hernández Hernández, M., 2010, 30-31).

In the Segura basin, margins, net average were assessed at 0.63 € / M3, and the values of production at 1.86 € /M3; facing an average value for a net margin of 0.29 Spain €

/M3. (Ministry of environment, 2003: "the water in the Spanish economy: situation and perspectives").
These systems are the most productive in the southeast of Spain. In the year 2000, highlighting low table grape vineyard productivity undercover mesh in 2.12 €/ M3, flowers in a greenhouse in 6.60 €/ M3 and vegetables in a greenhouse at 9.67 €/M3. (Avella, L.; Safe, P.; Martinez, C.; 2010).

The "E. coli" crisis in Germany in the year 2011 has had a clear impact on demand and prices for the products under cover in the southeast of Spain. The pepper in the alhóndiga Sun and Earth (SOLTIR) in San Javier (MURCIA) was auctioned in origin an average of 0.50 € / kg price well below the received in previous campaigns.
In the Region of Murcia under greenhouses predominate crops of tomato (57,04%), peppers (25.91%), melon (6.80%), flowers and ornamental plants (4.21%), watermelon (2,49%) and cucumber (2.14%).

The annual average fruit and vegetable production of the 2007-2010 period was evaluated at 2.509.048,25 tons. Most of this volume corresponded to vegetables (61,60%), and the rest to citrus (22.12%) and non-citrus fruit (16.28%). Those two and a half million tons and vegetables, almost a quarter corresponds to production under the cover (23.22%).
The structure of this production under the cover corresponds to vegetables in greenhouses and padding around 480,000 tonnes (31,06%), and the remainder to non-citrus fruit especially grapes under meshes (22.03% 90,000 tons) and very little citrus under meshes (2, 70% about 15,000 tons). Many of these volumes are directed abroad, to other European countries such as Germany, France and United Kingdom.
Producing and distributing fruits and vegetables of the Region of Murcia is a source of employment. In 2007 the commercialization of fruits and vegetables of the 2.5 million tonnes produced in the Region, over half a million collected in the southern regions, Almeria and Alicante, and to a lesser extent in Castilla La Mancha; It generated an occupation of 85,000 workers, of which more than half were foreign immigrants. (GOMEZ
ESPIN, J.Mª, 2007, 136).

3.2 Legislation and directives

1. Regulatory and legal framework that affects the SECTOR
   RELATING TO THE PRODUCTION AND MARKETING OF FRUIT AND VEGETABLES
   - ☐ CMO of fruits and vegetables are collected in Regulation (EC) No 1234 / 2007 of the Council and in the implementing Regulation (EU) No. 543/2011, of the Commission and includes the regulation of exchanges and support the fresh products sector to improve its competitiveness.
   - ☐ Regulation (EC) no 889/2008 of the Commission of 5 September 2008 laying down rules for the application of Regulation (EC) no 834/2007 of the Council concerning the production and labelling of organic products with regard to organic production, the labelling and control.
     18.9.2008 is daily official of the Union European L 250/1

- ☐ SINGLE PAYMENT SCHEME with the rules of regulation of single payment in the sector of fruits and vegetables contained in the EC Regulation nº 73/2009
- ☐ DEVELOPMENT and the Regulation EC No 1698 / 2005, Council on support through the European agricultural fund for Rural Development (EAFRD) rural development, determines the actions envisaged in this area affecting the whole of the agricultural productions, including fruits and vegetables and to the improvement of the quality of life in rural areas.

2. Relative to pollution of soil with nitrate:

To. GENERAL legislation:

• Directive 91/676/EEC of the Council of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (DO L 375 of 31.12.1991). • Royal decree 261/1996, 16 February protection against pollution caused by nitrates from agricultural sources (BOE 11 March 1996, no. 61). • Order of 31 of March of 1998, the Ministry of environment, agriculture and water, which approves the code of good agricultural practices in the Region of Murcia (BORM Wednesday, April 15, 1998, no. 85).

B. REGIONAL legislation relating to the study area

- ☐ Vulnerable area of the Campo de Cartagena •
  - or Order of 20 December 2001, which is designated the areas vulnerable to pollution by nitrates from agricultural sources in the autonomous community of the Region of Murcia (BORM 31 of December 2001, no. 301).
  - or Order of June 27, 2011, of the Ministry of agriculture and water, that amending the order from the Department of agriculture on March 3, 2009, by which establishes the Community action programme on the vulnerable zone corresponding to the Pliocene and Quaternary aquifers in the area defined by Eastern irrigable area of the Tagus-Segura transfer and the sector of the coast of the Mar Menor (BORM Friday (5 August 2011, no. 179).

- ☐ Vulnerable area of the high Vega and average of the Segura River •
  - or Order of 22 December 2003, by which is designated the area vulnerable to pollution by nitrates from agricultural sources in the autonomous community of the Region of Murcia (BORM 5 of January 2004, no. 3).
  - or Order of June 27, 2011, of the Ministry of agriculture and water, that amending the order of the Ministry of agriculture on November 19, 2008, which establishes the Community action programme on the vulnerable zone corresponding to the aquifers of las Vegas high and half of the basin of the Segura River (BORM Friday (5 August 2011, no. 179).

- ☐ Guadalentin Valley Vulnerable area •
  - or Order of June 26, 2009, of the Ministry of agriculture and water which is designated the area vulnerable to contamination by nitrates of the

Guadalentin Valley, in the municipality of Lorca (BORM July 2009 3, no. 151). 13 the pollution of waters by nitrates from agricultural sources

- Order of June 27, 2011, of the Ministry of agriculture and water, which establishes the Community action programme on the area vulnerable to contamination by nitrates of the Guadalentin Valley, in the municipality of Lorca (BORM Thursday, July 21, 2011, no. 166).

Currently pending publication the Ministry of water, agriculture and environment, by which modify orders on November 19, 2008, March 3, 2009 and June 27, 2011, the Ministry of agriculture and water, to establish action programmes on vulnerable areas to pollution by nitrates from agricultural in the region origin of Murcia", consequence of environmental problems in the Mar Menor area.

4 Conclusions

Greenhouse industry is widely extent in Europe. It has estimated 220000 ha of greenhouses, 90 percent are covered with plastic and 10 percent with glass.

In Spain, the area dedicated to greenhouses, has increased significantly in recent decades, from 546 ha in 1968 to 62.065 ha in 2013 (MAAMA, 2013). The largest concentration of greenhouses is located in the South and Southeast of Spanish peninsula (Andalucía and Murcia) and the Canary Islands. Regarding Murcia, and considering the last decade from 2002 to 2008, the area of greenhouses increased, but from 2008 to 2013 a slight decline in the Region of Murcia is observed, decreasing from 2008 to 2013 in almost 2,500 ha (MAAMA, 2002, 2013). Regarding the total of crops of this kind in the Region of Murcia, 27.3% of the total crop in greenhouse is located in the Campo de Cartagena, as is the case with padding where a 19.8% is located in this region, as well as the 24.1% of the total of localized irrigation (CARM, 2016).

The most commonly grown species in greenhouses are vegetables with medium thermal requirements: tomato, pepper, cucumber, melon, watermelon, marrow, green bean, eggplant. For example, In Italy, cherry and cluster tomatoes were quite rare 20 years ago and now represent more than 50 percent of greenhouse production.

Soilless culture represents one of the main solutions for soil problems, have positive effects on the environment and improve fertilizer and water-use efficiency. This is especially the case in Mediterranean countries where shortage of good quality water is a major constraint in protected cultivation. At present, a relatively small proportion (approximately 10%) of growing media, which are very important for a good start to plant cultivation, can be used for the production of seedlings and transplants.

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