AN OVERVIEW OF THE SOUTHERN EUROPEAN GREENHOUSE INDUSTRY

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1. Introduction to the vegetable industry in the Mediterranean Europe.

One of the bigger concentration of protected crops in the world can be found in the Mediterranean region, with around 400000 ha, out of which around 100000 ha correspond to greenhouses (Baudoin, 1999) and the rest to low tunnels and mulching.

The biggest greenhouse areas are found in Spain with close to 46000 ha and Italy, close to 25000 ha. In France there are some 9500 ha (González-Real, 1996), in Greece 3800 ha (Olympios, 1999) and in Portugal close to 2000 ha.

Turkey is the non European Mediterranean country with the highest greenhouse surface, some 14000 ha (Sevgican, 1999).

Within the European Union the highest concentration is between 36°N (S of Spain) and 44 °N (S. of France and NE Italy).

Around 4000 ha are soilless cultivated, mainly with inert substrates that can be different depending of the country. Sand, perlite, rockwool, puzolanes and volcanic gravels are the most extended ones. The soilless crop area is increasing, in general, in the Mediterranean countries and 1600 ha are estimated in France for vegetables and flowers (Gonzalez Real, 1996), around 1000 ha in Spain, some 30 ha in Greece (mainly for cucumber and tomatoes) (Olympios, 1999) etc.

The very long history of horticulture in the Mediterranean basin has been an excellent basis that coupled with the recent technical progress has raised a highly populated region where natural conditions, horticultural experience and tradition, consumption culture for fruits and vegetables and new scientific and technological knowledge get integrated. This set of circumstances can explain the development and the fast changes that can be observed in the Mediterranean horticulture industry. The home markets and the global European market as a whole, conform a high demanding market for fresh good quality vegetables.

Also the diffusion of the positive values of the Mediterranean diet, very rich in fruits and vegetables, may have contributed to the increase of the vegetables demand in the European countries. The better transport facilities have finally contributed to the distribution of the products. The EU is self-sufficient in vegetables.

The importance of the vegetable production value of the Mediterranean Europe is very high. Vegetables account for some 27% of the agricultural production value in Spain and Greece and 18% in Portugal.

The main vegetable producing countries are Italy and Spain with 28 to 29% of the European Union and France with 16% (tables 1,2 and 6).

There are deep differences in the distribution of the products, depending on the production country. The most frequent is that three or more agents participate in the trade. In Spain more than 60% of the home market products follow this way (Segura, 1991) while in the central European countries the most usual is that only one or two distribution agents participate. During 1987 only 12% of the vegetable production was managed and distributed through grower associations (Segura, 1991).

The patterns of food consumption in Europe are becoming similar in the various countries due to the present diet trends, which are more demanding in nutrient quality and health problems prevention. As a result of it, a vegetable consumption increase is observed in the countries where this was traditionally low. Now those products can be obtained in the local market easily, with good quality and over a long part of the year.

This increase in consumption cannot be seen in countries like Italy, Spain, France or Greece because the food habits were already high due to tradition.

Foreign market trade is very active in some of the producing countries. From 1985 to 1995 the value of the exported Spanish vegetables and fruits has got been multiplied by a factor of 3 (Tables 3 and 4). Imports resulted multiplied by 7 in that period, though the ratio exports/imports is 4 to 1; but in 1985 the ratio was 10 to 1 (Kaiser, 1996). Greece has increased the export figures for some crops like water melon, from 140178 tons in 1995 to 160000 in 1998 (Olympios, 1999).

Table 1. Area and quantity for some of the main vegetables in Spain (1995)

crop	area x 10^3 ha	quantity x 10^3 tons
potato	210	4200
tomato	55	2840
onion	27	1000
lettuce	33	900
melon	43	860
sweet pepper	23	800
artichoke	18	250
cauliflower	15	300
strawberry	9	300
green bean	22	220

(Source: Anuario de la Producción Agraria 1998. Ministry of Agriculture. Madrid)

Table 2. Vegetable production in some Mediterranean countries (x 10^3 ton)

	Spain	Italy	France	Greece	Morocco
tomato	2840	5426	730	2000	ne
artichoke	250	521	100	32	39
onion	1000	448	192	150	260
cauliflower	300	490	411	49	ne
melon	860	380	269	135	163
strawberry	300	694	92	6	ne
sweet pepper	800	995	29	90	ne
water melon	730	790	4	619	144

(Sources Miguel, 1997; Annuario INEA, 1997)
ne: no estimation available

The Spanish vegetable production is placed among the tops in the world (Table1)

Table 3. Spanish and Italian vegetable exports (x 10^3 ton)

	1990		1995	
	Spain	Italy	Spain	Italy
tomato	333	21	759	115
sweet pepper	160	20	325	11
melon	147	76(1)	317	115(1)
lettuce	114	155	299	150
onion	233	34	288	58
water melon	132	(2)	283	(2)
cucumber	105	6	247	6
potato	98	292	210	334
strawberry	104	40	177	75
cabbage and broccoli	47	64	168	126
artichoke	18	11	23	12

(Sources: Anuario de la Producción Agraria 1998. Ministry of Agriculture. Madrid; Bianco et al., 1999)
(2) included in (1)

Table 4. Value of the most significant Spanish vegetable exports to the European Union

product	millions US$	$x10^9$ pts
tomatoes	620.3	98
sweet peppers	374.7	59.2
lettuces	221.5	35

(Source: Anuario de la Producción Agraria 1998. Ministry of Agriculture. Madrid)

The total value of the exported Spanish vegetables was almost 290000 million pesetas (1780.5 million US$) in 1995, while imports reached 39000 million pts (246.9 US$) (Table 5)

Table 5. Imports and exports of vegetables in Spain in 1995

total imports		total exports	
quantity (tons)	value million US$	quantity (tons)	value million US$
627,716	246.9	2,649,638	1780.5

Table 6. Spanish vegetable production and value

year	surface $x 10^3$ ha	production $x 10^3$ ton	value million US$	agricultural total production million US$.	%
1995	401	10615	3673	13548	27
1996	356	11406	4076,2	16417	25

(Source: Anuario de la Producción Agraria 1998. Ministry of Agriculture. Madrid)

The main grower goals in the nearest future should be addressed towards the direction of working in association with other growers in some kind of cooperative. In this way one of the objectivs, which is extending the production calendar in order to offer continuously a quality product, can be more easily accomplished. Also an efficient handling, grading, packing and labeling with quality granted brands can be more easily done in a cooperative way of working.

Already at the present, but even more in the future, grower is trying to progress in the preparation of the product for the market, going as ahead as possible in order to obtain the biggest part of the surplus value. Diversification is another priority, by means of new crops, but also new types, colors, sizes, etc.

Other important objetives are improving the quality of the products by reducing chemical residues with the introduction of integrated production methods, and protecting the environment, improving the greenhouse design and equipment and the introduction of soilles culture techniques.

2. The protected vegetable business in southern Europe.

The fruit vegetables, tomato, pepper eggplant, melon, cucumber, squash, water melon, strawberry, green bean, are prevalent in protected cultivation in the Mediterranean countries.

Tomatoes and peppers as well as other vegetables, are produced in Spain mainly along the seaside, Andalucía, Valencia, Murcia, but also in the Canary Islands the winter tomato production is very significant. Italy has the main greenhouse concentration in Sicily, Greece in Crete, France in the south-east and Portugal in the Algarbe, all of them very close to the sea coast.

The main destination of the products is the home markets, but an important fraction, more than 90% of the exported quantities, go to other European countries.

Holland is also an outstanding producer, with a high technological level that competes with the Mediterranean products.

Out of the European Union the major competing countries in the Mediterranean basin are Egypt, Turkey, Marocco and Tunisia. Some of these countries show a fast change in their installations and technology, and their possibilities of getting a part of the European market are becoming higher, also with the help of the international commercial agreements.

In order to face this situation, of increasing competition, the European growers are strongly oriented towards better technification, higher quality, product presentation, as well as to increase the diversification of products. Also as far as the technical facilities are improved, f.i., greenhouses with better chances for reducing climatic constraints, the possibilities for using non chemical means for plant protection increase, and this has a direct effect on the product quality for the market.

After 20 years of a sustained increase in the greenhouse area, with differences in some countries and regions, there is at the present a stagnant situation, and the grower objectives are clearly addressed towards technological improvement. In Spain this change of attitud is very obvious and already growers are reinvesting and capitalizing benefits in the nurseries through constructions and structures innovation, fertirrigation and climate equipment acquisition, as well as other facilities that contribute to the production and handling processes.

The regions of South Europe have a common climatic characteristic,which is the mild winter temperatures and the high insolation (Tables 7 and 8). This fact, in addition to the horticultural tradition as well as the improvements in the transportation systems, have been the basis of the protected culture industry in this region, with the goal of extending the products offer that were for years limited to spring and summer period and enlarging the number of destination markets (tables 9 and 10).

Table 7. Average monthly air temperatures (°C) in different Mediterranean locations

	latitud	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Barcelona	41	17	14	10	9	10	12
Valencia	39	18	14	11	10	11	13
Almería	36.5	19	16	13	12	12	14
Cartagena	37	18	14	12	11	11	13
Larissa	40	17	12	7	5	7	9
Ierapetra	35	22	18	15	13	13	15
Faro	37	19	16	13	12	13	14
Gela	37	21	17	14	13	14	15

Table 8. Global solar radiation in various European locations ($W.h.m^{-2}d^{-1}$)

	December	March	June
Almería (Spain)	2320	4400	7375
Ierapetra (Greece)	2380	4450	7950
Gela (Italy)	2145	4300	7200
Brussels (Belgium)	405	2375	5370

Table 9. Mean variation of the Spanish exports of tomato in the period 1989 to 1994 and the risk of prices fall (Caballer and Segura, 1996).

month	volume (tn)	value US$	price fall risk
Jan	500982	556646	increase
Feb	434092	482329	increase
Mar	397093	441182	increase
Apr	223676	248529	very high
May	116530	129478	very high
Jun	42214	46904	high
Jul	10351	11515	nil
Aug	3727	4141	nil
Sep	26910	29900	nil
Oct	183169	205244	nil
Nov	322719	358575	increase
Dec	503743	559715	increase

All along the 80's and the 90's a progressive increase of the soilless cultivation area has been observed in Europe, including the Mediterranean countries.

The Southern European protected crops industry is generally featured as a family business, with an average greenhouse area per nursery in Spain, of 0.5 to 2.5 ha. The work is carried out on the basis of the own family members, with the help of temporary labour that is contracted as required along the crop cycle.

Table 10. Main harvesting periods in Spanish greenhouses.

Almería	harvesting period	mean yield kg/m^2
tomato	October to June	8.6
green bean 1st	Sept. to Jan/Feb	0,87
green bean 2nd	Jan/Feb to July	
sweet pepper	Nov to June	5.5
	July to Jan/Feb	
cucumber	Jan to June	8.0
	Sept to Jan/Feb	
eggplant	Jan to June	6.8
	Sept to June	
squash 1st	Sept to Feb	6.5
squash 2nd	Feb to June	
water melon	Jan/Feb to July	5.9
melon	Jan/Feb to July	4.3

(continue)

Murcia and Alicante	harvesting period	mean yield kg/m^2
tomato	1/2 Oct. to July	10-12
tomato Daniela, Bond, Rento, Royesta, Bodar	Oct. to 1/2 April 1/2 April to Aug.	interplant; heated 14° soilless 32
tomato (truss) Durinta, Monica Katar, Magda	1/2 Apr. to June	16-18
sweet pepper . Lamuyo type Atol, Harmony	March to Aug.-Sept.	10-12 13-15 (heated 14°C) soilless
. Yolo type Orlando, Cascade, Torkal, Habana, Zafra, Oros, Fiesta, Roxy	March to Aug-Sept.	16 (heated 16°C) soilless
green bean maxi Iluro, Nuria Tauro	1/2 Oct. to 1/2 Sept.	2-3.5
melon Galia Galia, Dikti, Arava	1/2 May to 1/2 June	7-8
melon Cantaloup Licata. Castella,	May to 1/2 July	6-8
Sirio, Clipper, Toper	1/2 Oct. to Nov.	3-3.5
squash Belor, Excalibur, Elite	Sept. to 1/2 Apr.	4-4.5
eggplant Paula, Cava, Diva	Oct. to July	13 (soil), 22 (soilless)

The international markets of vegetables are more and more competitive due to the recent GATT agreements and the bilateral agreements between the European Union and third neighbour countries. Also the progress in the conservation and transportation technologies as well as the increasing power of the big distributors and changes in food habits, are demanding from growers and from the whole business to quickly adopt to the new situations.

In Spain vegetable trade is done through one of the three following distribution channels:

1. Local private auctions
2. Grower cooperatives
3. Other wholedealers

The local auctions are a kind of origin markets where growers go by themselves and pay a commission on the price the product is finally sold. In this way the grower cannot get any profit from the added value of his product. The grading and the quality are quite irregular.

By means of cooperatives and associations, growers participate in the product distribution and get the benefits from added values along the commercial channel. Products are carefully graded, standardized, labeled and packed.

These two are the main systems. In a recent study in Almería and Valencia (Martínez-Carrasco and Calatrava, 1996), resulted that almost 57% of the surveyed growers were using the local auctions and 39% the cooperatives, and in relation to the volume of handled products, 47% was traded through auctions and 42% through cooperatives.

The distribution by means of cooperatives involve a number of clear advantages for growers:

- they get a main part of the product added value

- they are in a stronger position to negotiate inputs prices

- also they can negotiate better with dealers, due to their offer concentration

- and their perception of the market evolution and requirements is higher, so that adapting to them can be faster

3. The production system in the greenhouse

3.1. The greenhouse

The surface of greenhouses in the World is higher than 450000 ha. This is mainly concentrated in China, Japan and Korea with 60% of it and the Mediterranean basin with close to 30% of the World greenhouse area. The first country is China with around 60000 ha and then Spain with 46000 ha and 70% of them in Almería, Murcia and Alicante. (Cobos and López, 1998).

The Mediterranean protected horticulture has been developed from the seventies in very simple artisan greenhouse structures, built with timber and iron wire. The Portuguese greenhouses were built with wooden vertical posts of pine or eucaliptus and beams of the same materiales for the plastic film to be fastened. This structure results in 7 to 9 m span and 2 to 2.5 m maximum height to the ridgebeam. In the South of Italy, in Sicily, structures are based in wooden posts 100 mm diameter or concrete posts and 50 mm thick timber beams on the roof. Spans are 5 to 20 m wide and 3 to 3.5 m high.

Similar types are built in Greece, with 5 to 10 m wide spans. There are 3000 ha of the traditional structures made of wood or wood and iron, but new improved designs are increasing in number (700 ha).

In Spain the highest extension of greenhouses has been associated to the structure named "parral" which is based in wooden posts 2.2 to 3.5 m long stuck vertically in individual concrete foundations and linked to each other by tension wires running across their tops. These wires give support for two wire nets in between which the polyethylene film is sandwiched. All the set is strongly stretched and fixed to the soil by means of tension wires tied to buried concrete blocks all around the perimeter.

This very light structure is able to stand strong winds without any problem when has been properly made and the cost is less than 7 US$/m^2 with the film included.

The roof was initialy horizontal and the height was lower than 2 m in arid regions with no rain, or with a light slope where some rain is expected to happen. In this case the height is 2 to 2.5 m to the eaves and 3 to 3.5 m to the ridge.

All the described constructions have only the possibility of side ventilation, which in the best case is less than 20% of the covered soil.

The main constraints of these popular greenhouses are:

- insufficient ventilation when solar radiation is high and temperatures get up in excess;
- water condensation on the film surface and dripping on the plants;
- film and structure fragility when the whole is not properly stretched and fastened, and early ageing of the film due to contact with such a rough structure elements;
- low winter light transmission when the main elements of the structure are wood pieces and the roof is low sloped;
- lack of tightness, which reduces the posibilities for using heating or humidifying equipment;
- difficulty for mechanized operations when the structure is too heavy and there is no open space for machinery movement;
- limited height and poor volume to area rate.

In the South of France the most simple greenhouses are iron frame walk-in tunnels, adapted to moderate rainfall and winds, 8 to 9 m width and with side ventilation, first manually operated and more recently automated; the normal cost is around 40 FF/m^2.

French growers are improving their greenhouses and the trend is for multispan arched roof structures, in some cases the arch is pointed, ogival arch, which results in a higher structure, allowing for condensed water drops to slip to the eaves and in addition, improves solar light transmission into the house when sun is low. These kind of structures have automatic ventilation, normally through roof vents, but also due to being heigher, up to 4.5. or 5 m, more side ventilation can be obtained if wanted. Also the thermal oscillation in these houses is smaller. The price is from 80 to 120 FF/m^2.

Though an important part of the total production is still produced in the old greenhouses, the Mediterranean grower is already convinced of the need of changes and many of them are involved in a process of improvements, in order to reduce the explained constraints and reach the new objectives, particularly the extension of the harvesting period, the better regulation of climate, especially during the months and hours of high temperatures, and the obtention of high quality products for an exigent customer in a competitive market.

The main changes that grower is promoting in the greenhouse are:

- substitution of wood structures for iron;
- increase of ventilation surface; higher rate of ventilation surface to soil area;
- higher greenhouses with bigger rates of volume to soil area and more sloped roof to gain 7 to 12% in light transmission and eliminate condensed water drops;
- combination of side and roof ventilation or substitute the only side vents by only roof vents;
- introduction of other plastics for greenhouse cover, like three layer films and high density materials like polycarbonate, PVC, PMM, of longer life and better thermal and optical properties;
- preparation of the roof as a rainfall water collector;
- general improvement of greenhouse equipment and management (heating, shading, cooling, fertigation).

In parallel to these improvements, an increase is also observed in the number of new industrial multispan greenhouses, some of them with partial or total cover of rigid materials. Most frequently these are arch roofed, with 6 to 8 m width, 4 m height, in some cases increased up to 6 m.

A deep change is then observed from the simple structures with wooden posts, iron nets and tension wires, with 1.80 to 2 m height, poor ventilation surface and manual operation to the new types which still have to be further improved.

The last innovations in Spain go towards multispan greenhouses with side walls between 2.5 and 4 m height, span width 6 to 9 m and 5 m between posts. The side walls are frequently covered with rigid materials, double wall polycarbonate for instance. The roof with thermic polyethylene and the ventilation openings with nets. This tight construction gives the grower more possibilities for climate control and pest and disease protection. It also opens a door to biological and integrated plant protection as well as to biological pollinators.

Ventilation in these houses is done through the roof vents which get open by oscillating 1/3 to 1/2 of the arch.

In the conditions of the Mediterranean coast of Spain, ventilation rates 20% higher (50 to 70 changes/hour) have been measured under sunny and low wind conditions with 10% side ventilation together with 5% roof ventilation, compared to only 10% side ventilation, resulting 1 to 2.5°C lower temperature difference with the open air (Montero, 1992).

Feuilloley and Mekikdjian (1993) developed simple descriptive models for natural ventilation through various modalities of Mediterranean walk-in tunnels. These models are useful for predicting the performance of greenhouses in practice. The optimal opening rates (vent surface to soil) are between 15 and 20% (Nisen et al., 1988; Feuilloley and Mekikdjian, 1993). They showed that the chimney effect of the roof vents is more important when wind speed is lower than 1 m/s.

The use of double cladding is very frequent. Average minimun temperature differences of 1 to 3°C are measured in winter compared to the single cover, and 10% increase in humidity during the day. There is also a 10 to 15% solar light reduction in December (Martínez, 1978; Martínez and Bimbo, 1992; Montero et al., 1987) which can be a limiting factor for the crop.

The most spread covering material is the polyethylene film of 100 to 200 microns, treated with protecting UV additives and with low transmision to long IR radiation.

The plastic materials available in the market at the present, are of a good quality and accomplish the standards which have been set up by different countries (Italy, Spain, France, Greece, etc.).

Other materials, which were known for years, are now starting to be slowly accepted in the improved structures, like PVC, PMM, polycarbonate in double wall and other more recently introduced materials:

- co-extruded three layer films that offer better light conditions
- photoselective films that absorbe UV and protect against Bemisia tabaci, vector of TYLCV virus, also against leafminer Liriomyza trifolii, aphids and thrips. These films block some wave lengths of the UV spectrum between 280 and 390 nm. Control of certain fungi has been observed as well, by means of sporulation and micellium growth inhibition in Botrytis, Sclerotinia, Alternaria and Stemphylium.

Various research teams are involved in the development of improved greenhouse structures in France and Spain (Montero and Sevilla, 1992; Castilla et al., 1997), though is not always easy to transfer the results to the industry. A simple proposal has been to increase side wall height to 2.5 m and ridge height to 3.5 or 4 m and form a saddle asimmetric roof with a lower slope facing north. Following Castilla (1991) these changes improved gross benefit by 24% as a result of light transmission inside the house.

3.2. Climate regulation. Equipment and management.

The resulting climate within the Mediterranean greenhouses has been along the years the product of the construction simplicity, the natural climate and the limited tools available to regulate or modify it. Since the vegetable production calendar has been nowadays much more extended than years ago and out-of-season cropping is not yet the only goal as it was, growers have to face a higher number of limiting conditions that can be summarized as:

- sub-optimal minimum temperatures along the cold season, including the risk of frost;
- excessive air humidity levels, condensation of water on the greenhouse cover and water dropping on the crop;
- over-optimal maximum temperatures during the clear days;
- high water vapour pressure deficits;
- depletion of $C0_2$ concentration in the air for some hours in the day.

Extreme temperature conditions and wide oscillations along the day course are normal under plastic greenhouses, limiting the growth and development of plants.

From the viewpoint of the climatic conditions, the main limitation in the Mediterranean greenhouses, is the temperature excess and the high vapour pressure deficit (VPD) in the air during the high solar radiation hours, which are frequent from the end of the winter. This is the reason why getting an efficient ventilation is a common goal for everybody, engineers and growers.

When leaf temperature increases, both the net photosynthesis and transpiration rates decrease from some levels which depend of the $C0_2$ concentration of the air. It is possible to get high photosynthesis rates with higher air temperature, when both, the radiation and the $C0_2$ concentration are high (Stanghellini, 1993). Radiation is normally high enough and is not a limiting factor in the Mediterranean region, but $C0_2$ concentration can descend more than 20% especially by noon, in greenhouses having a heavy canopy crop, high temperature (29 to 35°) and low humidity (40 to 60%), with poor ventilation (Aguilá et al., 1984; Lorenzo et al., 1990). This $C0_2$ depletion can worsen plant sensitivity to water deficit by inducing stomatal conductance increase when $C0_2$ gets too low.

For many years, numerous works have described in detail the various aspects of the Mediterranean greenhouse climate (Damagnez, 1974; Nisen, 1974; Martínez, 1978; Monteiro and Portas, 1986; Monteiro et al., 1987; Nisen et al. 1988; Baille, 1989, 1995; Castilla, 1994, 1999; Martínez, 1994; etc.).

Temperature excess is partially controlled by means of natural ventilation with the help of shading covers. The efficiency of natural ventilation is being improved at the present time by means of changes in the greenhouse structure, that result in a bigger ventilation surface to soil area ratio.

Side walls and ridge are getting increased in height in the new constructions as already explained. In this way the side openings can be increased in surface and the volume to soil ratio of the greenhouse is increased too, which helps in reducing extreme climate oscillations.

Many of the multispan new greenhouses are designed in this way and the width of each span is being reduced to some 6 m. This, in combination with roof ventilation openings, is an efficient way for improving the global environment and avoid many troubles to the grower.

The control of excess incoming radiation, as a means to reduce temperature and VPD in the greenhouse, is currently done by means of white wash spraying over the film cover. The main interest of this simple way is the low price, since its efficiency is far from grower wishes. The use of black or white shading nets is not much difussed due to higher costs.

Table 11. Growing conditions in Summer in a PE greenhouse with different shading materials, in Valencia (Spain) with a crop of gerbera

	whitewash	outside white net 5 x 3	outside black net 5 x 3	open air
photosynthetic radiation $\mu M/m^2s$	765	699	550	1776
air temperature °C	36.4	36.4	34.2	31.3
relative humidity %	43	51	54	46
net photosynth.rate $\mu M/m^2s$	4.9	11.6	11.0	-
transpiration rate	16.0	21.2	20.3	-

But the problem is that these non movable shading methods produce a considerable decrease in photosynthetic rate and also, in many cases, the degree of control of VPD of the air is minimum (table 11). The ventilation efficiency is also reduced inside the greenhouse, as table 12 shows.

Table 12. Radiation levels and average maximum air temperatures in summer (July) in Valencia in polyethylene greenhouses covered with different shading materials. No crop inside and continuous side vents wholly opened. Vents to soil ratio 0.18.

type of shading	radiation ($\mu M/m^2s$)	air temperature °C
open air	1880	31.9
no shade greenhouse	1090	45.2
white wash cover	740	42.4
black net 5 x 3 out	510	39.2
black net 5 x 3 in	580	48.8
white net 5 x 3 out	640	43.6
white net 5 x 3 in	650	46.7

Francescangeli et al. (1994) also report on 2 to 3°C reduction as a result of whitewashing.

It is quite frequent getting from 0.2 kPa VPD in the night to more than 3 kPa at noon, as Lorenzo (1998) says. Even when plants are young, deficits as high as 5 kPa can be reached in Autumn an Spring. Natural ventilation is the normal way to try to control these conditions of humidity.

A technological step towards improving this problem is being adopted by some growers, still very few indeed, and it is the use of high pressure fog systems. With this technique well managed combined with ventilation, it is possible to reduce the temperature difference between the air of the greenhouse and the open air, even till cero or lower, depending on the degree of saturation deficit of the air (table 13). the most important effect of the system is humidity stabilisation of the air to levels which are suitable for the functions of the crop. This system is still expensive, but the grower interest on it is increasing. Clogging of the nozzles can be a problem when water contains salts.

A combination of a light shading with a humidifying system can be a high value tool for climate regulation during the hot months. As the air humidity gets higher, the ventilation rate must be increased in order to get the cooling effect from the fog (Montero et al., 1998).

Table 13. Climatic conditions in a plastic greenhouse with and without fog system, in summer in Barcelona (Spain) (Montero and Antón, 1994).

	open air	fog	no fog
total global rad Kwh/m²d	5.46	1.99	2.13
average daily temperature °C	24.8	25.7	28.7
absolute maximum temp	31.1	31.0	36.9
average max. temp.	26.9	28.5	32.6
average daily relat. humid. %	76.5	83.7	74.6
average 12-15 h rel. humid. %	74.9	83.4	72.0

When using normal low density PE film the minimum temperatures are similar in and outside the greenhouse. With the help of a low long IR transmission film, it is normal to get 1 to 3°C increase in the minimums and the mean increase is between 0.5 and 5.5°C (Martínez, 1978; Martínez and Bimbo, 1992; Montero et al., 1987; de Muynck et al., 1986).

The decission of using conventional heating is a matter of grower economical accounting. Heating systems based on a fuel boiler heating water and distributing it at 25 to 55°C, by means of polypropylene corrugated 25 mm pipes, laying on the soil close to the plants, buried in the substrate or soil underneath the plants, or suspended in the air along the plant rows, are the most spread.

The improvements made in the structure, which results in more tightness and thermal inertia, as well as better possibilities for using double covering, and the change of some growers towards the soilless cultivation systems, are convincing a limited number of growers to decide using some heating, which opens the way to new technical possibilities affecting the quality, such as the use of non chemical fruit setting means, and the biological pest control. A significant number of growers are following this methods with promising results.

The number of pipe tubes is very variable, from 3 to 10 m per m² and the air temperature is set at levels around the biological minimum of the crop, from 9 till 16°C depending on the species and type of cultivar; Martínez et al., (1985), Lorenzo et al., (1997), Martínez (1998), have shown how both, yield and quality can be improved with heating in the plastic houses, though, as Baille (1999) says, it is more an economical than a technical problem, since equipment investment and running costs can be high enough to reduce the benefit goal of a particular grower.

Light conditions in the greenhouse are determined by incoming solar radiation. The range of solar radiation in the Mediterranean region goes from 800 μM/m²s in winter to 2000 μM/m²s in summer. Normally, the real transmissivity factor in practice ranges from 60 to 70% of the incident radiation, even while the optometric properties of the covering material are the best ones. This means that in winter only some 500 to 600 μM/m²s will often reach the crop canopy and this amount is going to limit photosynthesis in many of the major vegetable species (Martínez, 1994).

This problem may become more important when grower decides to use a double cover (Martínez and Bimbo, 1992; Martínez, 1994) (table 14).

Table 14. Climatic conditions under single and double polyethylene cover and net photosynthetic rate of gerbera leaf (light saturation point around 700 μM/m²s) (Valencia, Spain)

	PAR μM/m²s	% lost rad.	temp.°C	humid.%	photosynthesis μM/m²s
Winter					
open air	879	-	12.5	62	-
single cover PE	570	35	21.6	66	12.0
double cover PE/EVA	456	48	24.0	82	9.5
Spring					
open air	1350	-	25.2	27	-
single cover PE	950	30	33.6	29	14.0
double cover PE/EVA	880	35	37.9	31.3	15.5

The problem of radiation deficit during the winter is then also affecting the Mediterranean greenhouse crops and there is the need to improve the growing facilities towards optimising the light balance in favour of the plants.

Reduction of the greenhouse structure is a generalized step, by means of substituting the wood by the iron elements. Grower is also paying more attention to the quality of the film and is becoming more demanding, not only in relation to the mechanical or thermal properties but with the optical ones too. He is already aware that dust adherence and water condensation are not the same in all kind of films.

The shape of the cover is also changing either to higher slope roofs than before, which is coupled with the need of higher structures, or to arched roofs. In both cases the winter radiation balance is improved. There is also an increasing number of growers, though still limited, that cover the whole soil with a white plastic mulch, that improves crop gain in light as well. In this respect Lorenzo et al., (1997) reported on less cucumber development (LAI) and lower intercepted radiation by the crop in winter, due to soil temperature reduction by mulch, in spite of the radiation balance improvement.

Results from Castilla (1991) and Castilla et al., (1999), associated to the slope and surface of the south oriented roof side, till a limit of 25° of inclination (table 15), have shown that every increase obtained in the light balance has been turned into a higher crop yield.

Table 15. Solar radiation transmission in polyethylene E-W oriented asymmetrical greenhouses depending on roof slope (Castilla, 1991; Castilla et al., 1999).

roof slope North/South	% solar radiation transmitted in winter (Dec.-Jan.)
flat	63.3
18°/8°	69.2
24°/11°	73.0
27°/45°	79.8

3.3. Water and nutrients

The use of the fertigation techniques, by means of localized irrigation supplying the water and minerals properly dosified and mixed from a unit provided with injecting, mixing and measuring devices and control elements as well as a performant distribution system, is generalized in the European Mediterranean greenhouses.

The grower is already familiar with automatic installations, programmers and is becoming familiar with the concepts of pH and electrical conductivity of the nutrient solutions.

The present trend goes towards a higher automation degree of irrigation through equipment with computer and software facilities that can help in the watering decission by means of climatic measurements, namely the amount of solar radiation that is related to the volume of water transpired.

The water dose is a result of the substrate water reserve fraction that the grower considers must be kept. Irrigation is normally started when a percent of the available water is consumed. This is the water dose, which includes a percentage for drainage requirements and the rest for plant consumption. When the plant has consumed this part, it must be supplied by the system. As this is directly related to an amount of solar radiation, the irrigation fequency can be managed by means of solar radiation measurements.

This relations between crop transpiration and radiation are known for some crops in some places, but this knowledge is still not generalized for the most of the Mediterranean vegetable areas, though it is available in other European countries.

The introduction of hydroponic culture is increasing the need of better accuracy in the water management, and growers that have changed to this system are becoming more interested in improving the knowledge and the efficient use of water and fertilizers.

In most of the Mediterranean European countries there is an increasing interest for the soilless cultivation systems and, more specifically, for hydroponic culture. In fact the surface is higher each year in some countries. In Spain there is a progessive change to hydroponics in some important greenhouse areas which have soil problems. The most extended substrates are local sands, perlite and coconut fibre, which are generally enclosed in coextruded black and white polyethylene bags.

Due to the low water retention capacity of these substrates and the high water demand of the Mediterranean climate, the management of water and nutrients must be very well controlled and irrigation frequency very high, in order to avoid or reduce the water deficit situations to the crop. Growers are already, but will be more in the near future, aware of this facts and promote a demand of equipment prepared to provide those technological needs.

Hidroponic culture is practised in Spain, and in general in Mediterranean countries, by means of open systems, since this technique is less difficult for non experimented growers, and simplify the problems when water quality is poor. At the present the use of closed systems is already introduced, with the goal of combining yield and quality with water and minerals use efficiency and respect to the environment. The closed system of culture will be generalised in some time but growers need the help and advise to solve the present problems.

There are some decissions and legislation in the European Union, affecting the way to follow for limiting environmental pollution related to horticulture:

- Directive 75/440/CEE, 16/6/75, of surface water quality requirements for human consumption in the member states.

- Directive 91/676/CEE of 12/12/91, for water protection against nitrate pollution from agricultural origin.

- Rule 2078/92CEE of 30/6/92, for methods of agricultural production compatible with environment protection needs

- Ordenance 261/1996 of 16/2/96, for water protection against nitrate pollution from agriculture

Following Alarcón (1998) the nitrogen disposal from intensive horticulture may reach 2000 kg/ha year.

The annual losses through drainage water in soilless cultivation are estimated in 2000 to 3000 m^3 water per hectar and more than 1 ton of nitrates.

In the case of tomato in rockwool the figures are:

Table 16. Inputs and losses of water and nutrientes in an open tomato rockwool culture (Jeannequin, 1993)

	inputs per ha	losses per ha
water	5831 m^3	1707 m^3
fertilizers	4459 kg	2588 kg
nitrates	1205 kg	780 kg
potasium	1768 kg	1033 kg

The irrigation management in soilless culture is done at the present through following up electric conductivity trend and ratio of drained solution. Some growers have improved it by means of a scale regulated to switch on the irrigation pump when a number of plants and substrate on it reaches a proportion of water loss. There are a number of similar systems to control irrigation frequency.

More growers are getting computer controlled systems which by now are only able to manage irrigation in relation to solar radiation. This means that growers are now more interested in the good performance of irrigation and nutrition, and will be open to possible suggestions to improve it.

There are at the present research teams working in models that will be useful for the irrigation automatic management, as well as for solving the problems of recycling the nutrient solution in closed systems, which are main objectives for soilless culture.

Following González-Real (1996) and Macía (1997) the water savings in a closed system amount for 22 to 25% and 40 to 80% of the minerals are saved depending of what nutrient, a 50% for N and 39 to 45% for P and K

As De Kreij (1995) pointed out, when changing from an open to a closed system, the standard solutions for each crop have to be modified, since the ratios of bivalent ions and of those whose uptake is lower should be reduced in order to compensate changes in chemical equilibrium of the formula.

4. Prospective of the future and conclusion

The most remarkable challenge for the future of protected cultivation in the Mediterranean region, is making it compatible with the general demand of quality of life. This can be considered in two different directions, one is the food and health quality for the consumer and the grower and the second is the environmental quality by means of decreasing the polluting effects on environment. This have to be done in spite of that intensification of the system will most probably increase in the coming years.

This challenge will require progressing in a wide front, the determined limitation of residues, either those originated in the productive process, plastics, packing, fertilizers and agrochemicals in general, or the agrochemical residues in food products. A wide number of disciplines and techniques have to contribute in solving these problems which have to do with the greenhouse design, the climatic regulation, the technology of materials, namely plastics, the management of the water and mineral nutrition of the crop, the knowledge and the difussion of biological or integrated cropping in the Mediterranean countries. The future of the industry is highly dependent of the progress and capacity to get adapted and satisfy the new needs.

On the other side, the grower faces the changes in the market scenery. The distribution of vegetables is becoming more concentrated and there is also more concurrence of products coming from the southern hemisphere, and all this increases competitiveness and makes it harder to cope with.

The only way for the grower is strictly controlling production costs and participate efficiently and with energy in the distribution processes. The offered product must be of high quality, health certified, well identified by means of quality and origin labels. Working involved in a cooperative or professional association gives the chance of that kind of product preparation and of concentrating the offer, so that grower can defend his products from a stronger position, assuring more participation in the marketing process.

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