Castilla, N., Hernández, J. and Abou-Hadid, A.F. (2004). STRATEGIC CROP AND GREENHOUSE MANAGEMENT IN MILD WINTER CLIMATE AREAS. Acta Hortic. 633, 183-196
DOI: 10.17660/ActaHortic.2004.633.22
https://doi.org/10.17660/ActaHortic.2004.633.22

Strategic Crop and Greenhouse Management in Mild Winter Climate Areas

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Keywords: technological level, costs, structure, equipment, climate, markets

Abstract

In the last decades, the increase of protected cultivation in glasshouses has been very scarce as compared with the large spread of low-cost plastic greenhouses around the world. The greenhouse area in northern Europe has been almost stable, while protected cultivation expanded enormously in the Mediterranean basin, enhanced by the enlarging demand of vegetables for the export and domestic markets, resulting from economic development. In the past, the production strategies in the Mediterranean greenhouse industries have been mainly related with the adaptation of the crops to a suboptimal environment, due to the limited greenhouse climate control. There is now a general trend to better equipped greenhouses with improved climate management, in order to increase product quality. Achieving an economic compromise between the higher costs of improved greenhouses and their increased agronomic production are requiring different solutions, according to the local technical and socio-economic conditions, in order to produce proper quality commodities at competitive levels, relative to the higher performances of the sophisticated glasshouse industry of northern European countries. The distance from the European markets, in export focused production, increases the transportation cost of Mediterranean production, limiting its competitiveness. The rise of the technological level in the "Mediterranean greenhouse agrosystem" includes diverse improvements related with greenhouse design and climate management, crop techniques and practices (cultivars, cycles, plant protection, irrigation, substrates,...) and market-oriented production strategies in the various conditions of the Mediterranean basin. The cultural level of the growers in different countries can be a limiting factor to improving the technological level of the greenhouses, and great efforts are being made to transfer this knowledge to the growers, providing them with the methodology of optimization of their production systems.

INTRODUCTION

During the last decades, the increase of the glasshouse industry around the world has been quite limited as compared with the enormous spread of plastic greenhouses. The Mediterranean basin (including all the countries of Africa, Asia and Europe limiting the Mediterranean sea, located between 30°N and 46°N latitudes approximately), the leading area in protected cultivation in the past (over 65,000 ha of greenhouses and high tunnels in 1987; Nisen et al., 1990), reached in 1999 around 144,000 ha of greenhouses and high tunnels (Castilla, 2002). On the contrary, the greenhouse area in the countries of the

European Union (excluding the Mediterranean) is around 20,500 ha (von Elsner et al., 2000), with small variations in the last two decades.

The percentage of plastic-covered greenhouses (high tunnels are included within greenhouses in this paper) exceeds 95% in all the Mediterranean European Union countries (reaching 99% in Spain, 98% in Portugal, 95% en Greece, 91% in Italy) while in the Northern European Union countries it is very low (2% in the Netherlands and Denmark, 5% in Belgium, 10% in Germany) (von Elsner et al., 2000), glasshouses being predominant. This generalised rise of the plastic greenhouse industry has been mostly based on the use of low-cost structures.

Upon examining other important areas, such as Japan, the leading country in greenhouses area years ago, (40,259 ha in 1983, reaching 52,571 ha in 1997) glasshouses also represent a small part (5%) of the industry (Ito, 1999). In China, the total area of greenhouses, practically non-existent in 1980, climbed up over 177,000 ha (lean-to-type greenhouses) and 186,000 ha of high tunnels in 1996, while the glasshouse area was limited to 60 ha (Zhibin, 1999).

The current situation of protected crops in the Mediterranean area has been recently described (La Malfa and Leonardi, 2001; Castilla, 2002). In the past, there has been a general tendency with production strategies to adapt the plant to a sub-optimal environment, rather than enhancing the greenhouses to optimize the micro-climate (Castilla, 1994). The consequence was low crop productivity and limited quality in some moments of the cropping cycles.

This tendency has a limit, and adequate climate management is now necessary in order to improve greenhouse production in the region (Baille, 2001). The strong competition arising from the globalization of both markets and production highlights the need for increasing the quality of produce through improved climate control. Achieving an economic compromise between the higher costs of improved greenhouses and their increased agronomic production is requiring different solutions, according to the local technical and socio-economic conditions, in order to produce proper quality commodities at competitive levels (Castilla, 2002).

This paper presents a general overview of the current situation of greenhouses and crop management in mild winter climates areas, with special reference to the Mediterranean area and preferently focussed on vegetable crops.

VEGETABLE PRODUCTION COSTS

The energy crisis and the introduction of plastic film (Tognoni and Serra, 1988) were major contributing factors to the shift in European greenhouse vegetable production to the Mediterranean region where the low-cost, plastic greenhouses and the development of simple technologies enabled the production of low-cost, out-of-season commodities (Monteiro et al., 1988) in a region where the climatic advantages are related to the high radiation conditions in the autumn and winter, the mild winter temperatures and the climatic stability influenced by the vicinity of the sea (Short and Bauerle, 1986; Castilla, 1994).

This “Mediterranean greenhouse agrosystem”, a good example of the greenhouse industry in mild winter climate areas, is characterised by the low technological and energy inputs (Baille, 2001). The use of simple structures, a generally low level of technology, and the lack of equipment for climate control, which are typical characteristics of Mediterranean greenhouses, create a very strong dependence of the greenhouse microclimate on external conditions (Castilla, 1994; La Malfa and Leonardi, 2001). This limits the potential yield, product quality, and the timing of production, but allows a low cost of production compared with the northern European greenhouse industry (Hernández and Castilla, 2000). On the contrary, the “Northern greenhouse agrosystem”, developed in the North of Europe, is based on sophisticated structures, with high technological and energy inputs, that require important investments. Obviously, the crop performances are better than in the “Mediterranean greenhouse agrosystem”. The higher costs of the “Northern greenhouse agrosystem” have lead to an important presence of ornamentals (of larger added-value as compared with vegetable crops) relative to the Mediterranean greenhouses.

In the middle of the nineties, the growing competition of Mediterranean countries producing vegetables, and countries like Kenia or Colombia producing flowers, almost led to a saturation of the European markets at times (van Uffelen et al., 2000). Parallelly, new marketing structures avoiding the auction system appeared, and the growers groups started selling their produce directly to the supermarket chains, in an active marketing approach (van Uffelen et al., 2000). These new marketing channels were effectively used by the associated Mediterranean growers to supply the European markets with greenhouse vegetables.

In spite of the enormous variability of production costs, typical of the Mediterranean greenhouses agrosystem (Calatrava et al., 2001), in order to give a very general outlook of the problem of competitiveness in the European market, Table 1 summarizes for tomato, sweet pepper and cucumber, the production costs and the integral costs on the market, for the best Dutch and Spanish growers.

Although details about quality were not seriously considered in the data set for Table 1 which, therefore restricts the validity of the comparison (Uetretcht, 2000), some clear differences emerge. Yields appear much higher in the "high-tech" Dutch greenhouse agrosystem, but production costs are also higher. On the contrary, the sales costs in Spain are substantially higher than in the Netherlands, as a result of higher transport costs (Verhaegh and de Groot, 2000).

The increase in yield and the reduction of unitary cost in the "Northern greenhouse agrosystem", two prime objectives in the former years, has been substituted by a particular interest on quality and differentiation strategies in order to meet the market demands (Taragola and van Lierde, 2000).

Table 2 provides a general picture of the cost of greenhouse tomatoes grown in Morocco. Though yields are now restricted by the limited export calendars to Europe, production costs are lower than in Spain, but the increased transport costs reduce the differences. The possible extension of the growing cycles in the future in Morocco and the consequent increase in yields will help to enhance the competitiveness, if the transport costs do not vary significantly. Therefore, the key influence of greenhouse site selection on the costs of the produce is due to both the production (as agronomic performances depend on local microclimate) and the marketing costs.

The composition of the variable tomato costs in both agrosystems (Table 3) shows the importance of salaries in both cases. The high cost of labour in mild-winter greenhouses limits crop productivity (Monteiro, 1994) and demonstrates the importance of increasing labour efficiency. Fertilizer and pest control costs are lower in the Mediterranean agrosystem. The cost of water is low, relative to the total production costs of greenhouse vegetables in the "Mediterranean agrosystem" and inexistent in the "Northern greenhouse agrosystem", as stored rainwater in those countries covers the irrigation requirements. The larger difference in the variable costs composition is the 35% cost of natural gas for heating and carbon dioxide injection in the "Northern greenhouse agrosystem" (Table 3).

GREENHOUSE TECHNOLOGICAL LEVEL

The large differences in greenhouse design and technology within the various Mediterranean countries do not allow the definition of a standard and specific technology for the region (Monteiro, 1994). In the past, the various levels of greenhouse technology when combined with adequate management strategies enabled profitable production systems (Castilla, 1994). For optimal profitability, greenhouse production in mild winter areas, such as the Mediterranean region, requires specific greenhouse design and environmental control equipment (Hanan, 1990; Castilla, 1994; Baille, 1999).

Site selection appears to be the key aspect of the profitable greenhouse production, specifically for the microclimate conditions, but also for other technical and socioeconomical aspects (water and electricity supply, communications, labour availability,…) that influence production costs and competitiveness.

Improving climate control and irrigation and soilless techniques were considered as the prevailing priorities for Mediterranean greenhouse growers (Baille, 1994), in order to raise their technological level. The growers investments in irrigation and fertigation equipment was the first step taken.

The main climatic problems to solve in this region, are related not only to climate control during winter, but also to limiting excess temperature and compensation for inadequate air humidity during late spring and summer (Baille, 1999). However, economical factors limit the investments required to achieve this (Castilla, 1994). The solution is to find a compromise between the enhanced agronomic performance of improved greenhouse production systems and the corresponding increase in cost, which must be compatible with the financial capacity of the growers (Baille, 1999).

Greenhouse Structure

In the Mediterranean area, most greenhouses are still of the low cost type. The wide assortment of plastic films offers the grower the possibility of improving radiation transmission both quantitatively and qualitatively (Baille, 1999). Increased use of long life and thermal polyethylene (PE) films has been reported in most countries, substituting for conventional PE film as a first step. Multi-layer films that combine the desirable characteristics of various materials (anti-drop, diffusing direct radiation, high PAR transmission, anti-dust, UV absorption, high IR absorption) are spreading as a second step (Morales et al., 1998). The photoselective plastic films that influence the extent of crop diseases (*Botrytis*, ...) or alter the behaviour of insects (influencing their vision) by blocking certain intervals of the solar radiation spectrum (Papadakis et al., 2000) are now commercial. New plastic films, more adapted to Mediterranean conditions (they can limit solar heating without reducing light transmission) are being developed (Verlodt and Vershaeren et al., 2000). Other special covering materials, like fluorescent and coloured plastic films, can be of interest so long as they do not reduce PAR transmission, but their use is restricted to the most developed countries.

Increasing radiation transmission in Mediterranean greenhouses, especially in the autumn and winter seasons, has been reported to be one of the most effective methods to increase yield and quality (Castilla, 1994; Erkal and Ergun, 1994; Castilla et al., 1999). The general trend in improving greenhouse design is by increasing roof slope to enhance radiation transmission and to evacuate condensed water (Baille, 2001), and building higher structures adapted to local conditions (Abak, 1994; Patsalos, 1999; La Malfa and Leonardi, 2001), as well as better isolation. Greenhouse site selection, due to the influence of local microclimate, is a key aspect for future agronomic and economical performances.

Covering the greenhouse structure with nets (screens), a technique initially used in very mild winter temperature zones (Castilla, 1994), is spreading for spring or summer growing in the highlands (Castilla et al., 2001; La Malfa and Leonardi, 2001).

A range of devices for collecting rain water from the greenhouse roof has been developed. Collected and stored rainwater can meet approximately 30% of the evapotranspiration demand (Abou-Hadid, 1997), which can be particularly important in arid areas. The high quality of this water is of great interest for soilless culture.

Greenhouse Climate Management

Heating is scarcely used in the Mediterranean region due to high cost. It is only used in high technological level greenhouses, or for frost protection by way of pulsed hot air heating systems (Tuzel and Eltez, 1999). Heating is more an economical than a technical problem (Baille, 2001) but requires an appropriate technological level of the greenhouse to be used profitably (Hernández and Castilla, 2000). Low temperature, hot water heating systems, that use plastic tubes for heat distribution, are preferred to high temperature systems that require steel tubes. Geothermal water for heating is used in some areas (Tunisia, Turkey) where this resource is available (Abou-Hadid, 1997; Tuzel and Eltez, 1999). Water sprinkling on the greenhouse roof for frost protection is used in Turkey (Tuzel and Eltez, 1999). Thermal screens can effectively increase greenhouse night air temperatures by up to 5 or 6°C, if they are properly installed (Baille, 2001). It is important to avoid the loss of light, when using shading.

Poor ventilation, on account of the general use of only lateral vents, is a typical feature of Mediterranean greenhouses (Castilla, 1994). Roof vents are being increasingly incorporated into low cost plastic greenhouses. However, most greenhouses in developing countries have no roof vents.

Cooling is the most important management aspect of Mediterranean greenhouses (Baille, 2001). Cooling can be accomplished by way of roof ventilation and taller greenhouses which increase ventilation efficiency by a chimney effect. Air fogging is being increasingly used (Castilla, 1994) but requires good quality water.

Low pressure, inexpensive fogging systems can be a good solution for cooling low cost greenhouses, provided the fog system is driven by a short time response VPD control (Montero and Anton, 2002).

Besides other technical aspects of greenhouse cooling, the most important challenge for the future is to quantify the cost-benefits associated with the cooling alternatives needed to achieve a given return (Willits, 2000).

Dehumidifying the greenhouse air reduces the need for ventilation and saves energy, water and CO_2 (Campen and Bot, 2000) but it is not yet economical (Nara et al., 2000).

The general trend of increasing roof venting area (relative to total greenhouse surface area), to proportions that can exceed 30% (Patsalos, 1999), is encouraged by the growing use of insect-proof nets (La Malfa and Leonardi, 2001) to prevent viral diseases, that substantially limit ventilation. Insect-proof nets (screens) are common in over 90% of the greenhouse area of Spain, and improved ventilation equipment is required to restrict high air humidity which contributes to the incidence of fungal diseases (Tuzel and Eltez, 1999). The wide use of mulching helps to reduce air humidity and limits crop water requirements, by reducing evaporation from the soil surface (Castilla, 1994).

Mulching with white PE film, a technique widely spread in sophisticated greenhouses, reduces yield when used in Mediterranean unheated greenhouses, due to the lowering of soil temperature in the winter (Lorenzo et al., 1999). Therefore, all these techniques developed for sophisticated greenhouses of northern areas should be tested prior to their generalised use in the "Mediterranean greenhouse agrosystem".

Whitewashing is a common practice in Mediterranean greenhouses to limit temperature in high radiation periods (Lorenzo et al., 1990; Tuzel and Eltez, 1999). However, as whitewashing reduces light within the greenhouse and consequently reduces production (Hernández and Castilla, 2000; Baille, 2001), it should only be used when it can positively affect fruit quality (Castilla et al., 2001). If shading screens are used to limit radiation to prevent high temperatures, they should be placed outside the greenhouse (Baille, 2001).

Carbon dioxide (CO_2) enrichment is more an economical decision than a technical problem. It is scarcely used because the enrichment periods are limited by the ventilation requirements of Mediterranean region greenhouses (Castilla, 1998). Avoiding CO_2 depletion with an efficient ventilation is a first step to limit photosynthesis rate decay (Martínez, 1992; Stanghellini, 1992). Intermittent CO_2 enrichment, in order to reach 600700 ppm when the greenhouse vents are closed, has been recommended (Lorenzo, 1999).

The restriction of wind inside greenhouses highlights the importance of air movement for the efficiency of photosynthesis, especially in calm days when CO_2 supply to the leaves can be a limiting factor. The use of fans for removing and mixing the greenhouse air is spreading in the Mediterranean region.

In the various conditions of the Mediterranean area there is a need for knowledge of crop response, not just technically but economically, to improve climate control and greenhouse design (Baille, 2001).

The improvements of light transmission, of natural ventilation and of cooling in Mediterranean greenhouses appear to be most promising for the rise of crop performances (Montero and Anton, 2002).

The next step, after a simple automation system to improve microclimate, will be the use of computerised control systems, whose effectiveness will be very much dependent on proper education and training of the growers (Baille, 2001). Simple decision support systems (DSS) are available for climate and crop management in the Mediterranean area, but its use is limited to the best growers.

CROP TECHNIQUES AND PRACTICES

The differences in species and cycles between countries (obviously influenced by the local climate) are more variable in tomato than in other species (Monteiro, 1994).

The sub-optimal microclimate conditions within greenhouses of the Mediterranean region, make it necessary to enhance fruit-setting in some periods (La Malfa and Leonardi, 2001). Despite the increasing use of insects for fruit-setting (honey bees and bumble bees), which is widespread in European countries (La Malfa and Leonardi, 2001), auxins are still used with tomato and eggplant in developing countries. The vibration of tomato is common when viable pollen is available (Tuzel and Eltez, 1999).

Plant Protection

Integrated pest management (IPM) has appreciably limited the use of pesticides in the Mediterranean greenhouse industry (Baudoin, 1999). Integrated production and protection (IPP) management programs that deal with pest and disease complexes affecting the crop, have been developed (Hanafi, 1999).

An effective IPP management strategy for protected cultivation must also include general plant hygiene measures inside and outside the greenhouse, removing and destroying all crop residues, the use of appropriate cultivars, proper irrigation and fertigation scheduling, and the use of adequately ventilated greenhouses (Papasolomontos, 1997). Complementary measures for the control of pest and diseases should include rotation, soil solarization, grafting on resistant rootstocks, proper ventilation, optimising plant density, use of adequate cladding films (thermal, anti-drip), mechanical barriers (vents-netting), and double doors (Papasolomontos, 1997). Reduction in chemicals is also a result of IPP management; the use of bees (bumble and honey bees) for pollination limit spraying with broad spectrum pesticides (Hanafi, 1999; Baudoin, 1999). Future prevailing horticultural problems will be pest problems, due to monocropping, globalisation of environment and environmental regulations (Cantliffe, 1999).

Irrigation and Soilless Culture

Greenhouses appreciably increase crop water use efficiency (WUE) relative to open-air grown crops (Stanghellini, 1992; 1994; Castilla, 2000; Baille, 2001;), particularly when localized high-frequency irrigation systems, such as drip, are used. This increase in WUE has been suggested as one of the main reasons for the spread of protected cultivation throughout the world (Wittwer and Castilla, 1995). Over 80% of the greenhouse area is drip irrigated in countries such as France, Italy, Turkey and Morocco. In Greece, Spain and Portugal nearly all greenhouses are equipped with drip irrigation systems. The salinity of irrigation water and inadequate scheduling are constraints on efficient irrigation management (Castilla et al., 2001).

Recovering and storing rain water from the greenhouse roof (Abou-Hadid, 1997) and the use of mulching can improve water management, in order to reach the high levels of crop transpiration needed for high production (Stanghellini, 1994; Baille, 1999). High WUE induces an improved fertilizer efficiency contributing to reduce fertilizer leaching (particularly N) and to limit the nitrate content of produce (leafy vegetables), contributing to the sustainability of the "agro-system." There is a clear trend of improving the control head of drip irrigation systems. The use of microcomputers for irrigation scheduling is increasing and the fertigation equipment is being improved (Castilla, 2000).

Soil-borne disease problems influenced by monoculture, and limits to the use of methyl bromide for soil disinfection, are encouraging the adoption of substrate (soil-less) culture, especially in the European countries. In the Almería area (Spain), almost 20% of the greenhouses use soil-less culture (Parra et al., 2001). The high cost of the system and the inadequate water quality, in some areas, are limiting its expansion. Appreciable areas in France (1,400 ha), Italy (700 ha) and other countries show increasing interest of growers for substrate (soil-less) systems. Rockwool, perlite, sand, and coconut fiber appear to be the most commonly used substrates, although a variety of local materials are being tested. The use of re-circulating soil-less systems, which have very low environmental impact, is very limited, due to the difficulties of salinity and pathogens management. However, serious efforts are being made to develop simple systems adapted to Mediterranean conditions.

Although there are appreciable differences between the various Mediterranean countries, all of them show a generalized tendency to increasing sophistication of their greenhouses and associated equipment.

GREENHOUSE STRUCTURE AND EQUIPMENT COSTS

Various types of improved greenhouses have been proposed for the Mediterranean area, but agronomic and economic comparative studies are scarce (Castilla et al., 2001). In order to assure their economic viability the investments in greenhouse structure and equipment should be limited (Castilla, 2002).

For tomato cultivation in Greece, cheap greenhouses have been reported as more profitable (Tzouramani et al., 1995), probably because the economical benefit of growing in better (and more expensive) greenhouses is not clear, if they just increase yields but not the market price of the produce (Monteiro, 1992).

As an example of the diverse options in the "Mediterranean greenhouse agrosystem", Table 4 presents the greenhouse structure construction costs in the south of Spain. The old "parral" type structure, with only lateral vents and no climate control, cost around 6.0 euros/m^2. The improved "parral" type greenhouse (higher roof slopes, roof vent) construction cost is around 8.9 euros/m^2 and the arched-roofed multispan reaches 13.8 euros/m^2.

As those structures are progressively equipped for better climate control, the total construction costs for the improved high roof slope ("parral" type) greenhouse is between 8.9 and 14.0 euros/m^2 (Table 5). The arched shaped multispan greenhouse total construction cost varies from 13.8 to 34.5 euros/m^2 (Table 6). The average extra investments for greenhouse growing (that include the soil clearing, levelling and preparation, the drip and soilless systems as well as the proportional parts for the water reservoir, building and electric costs) are around 5.8 euros/m^2. Obviously, the technological level of the equipment should be chosen according to the greenhouse structure type.

These values are quite distant from those of the Venlo greenhouse type, typical of the "Northern greenhouse agrosystem", whose mean cost oscilates between 75 and 80 euros/m^2, for the fully-equipped high-tech glasshouses, in the north of Europe (Benoit, personal communication).

The price of the land is an important aspect of greenhouse investment cost, as urbanization in any country generally requires the most valuable farm land (Cantlife, 1999), specially in touristic areas where a competition between the agriculture and tourism industries appears for land and water resources.

In the past, the maximum quantity, duration and uniform availability of solar radiation for plant growth was required for greenhouse design, complemented with adequate structural strength, low cost of construction and low operating costs. The best design was supposed to be a compromise between those requirements giving the highest financial returns (Bailey and Richardson, 1990; Giacomelli and Ting, 1999). For the future, complementary requirements should be limited use of energy, substituting fossil by alternative energy sources as far as possible, and minimum environmental impact, therefore recirculating the irrigation water in soilless systems, recycling waste streams and extending the biological control of pests and diseases (Ammerlaan et al., 2000).

ENVIRONMENTAL IMPACT

Along the last years in Europe, society has become increasingly concerned with the environment, and a general trend for reduce use of energy, pesticides, chemicals and waste has emerged (van Uffelen et al., 2000). General legislation has determined that growers must limit the emission of polluting agents in the European Union (van Os and Benoit, 1999).

Recently, the high input of energy in the greenhouses of northern Europe, using fossil fuels which cause environmental pollution, drove the greenhouse industry to a more efficient use of energy, such as natural gas, which has a lower environmental impact (de Cock and van Lierde, 2000). Even so, the use of fossil energy represents for more than 50% the total environmental impact of the Dutch glasshouse industry (Ammerlaan et al., 2000).

Different authors have recently reported that the closed rockwool culture system can reach similar and even better yield and fruit quality than the conventional open rockwool system (Papadopoulos et al., 2001; Schnitzler and Gruda, 2002). So, the modern "high-tech" greenhouse shows the greatest potential for healthy and environmentalfriendly production (biological control, re-circulation), but this clashes with the ideal of "natural" production methods (Larsen and Buwalda, 1998).

Various methods of analysing the energy inputs and efficiency (Lagerberg, 2000) and assessing the environmental aspects and potential impacts associated with a product or a system (as Life Cycle Analysis – LCA) have been described (Anton et al., 2002), but there are no studies relative to the "Mediterranean greenhouse agrosystem".

The recycling of waste can be very important, as the re-use of plastic would contribute to productivity and energy efficiency increases (Baker et al., 2000). Limiting the environmental impact of protected culture must also include the saving of natural resources and the reduction of wastes. The recycling of plastics must be a primary objective in those countries that have not yet considered it. Currently, in the Almeria area (Spain), over 90% of the greenhouse plastic residues are recycled.

MARKETING Quality

Quality is a combination of attributes, properties or characteristics that give each commodity value in terms of intended use. Quality components are: appearance, texture, flavour and nutritional quality factors and the relative importance of each quality component depends upon the commodity or the product and how it is utilised, and varies among producers, handlers and consumers (Kader, 2000).

Consumer confidence in food safety and production methods is at an all times low (Viaene et al., 2000). A decade ago, food scandals in the European Union (mad cow disease, …) remarked the need to guarantee food safety by good farm hygiene (van Uffelen et al., 2000); this issue became very important in the United Kingdom and strict production protocols were established for growers within the new marketing structures (detailed cultural methods to be use, introducing the traceability of the products, …) in order to guarantee food safety. The newly emerging consumer demands for safe, healthy, high quality and convenient products (Viaene et al., 2000).

The necessity of shipping mature fruit-vegetables long distance has encouraged harvesting them at less than ideal maturity, resulting in suboptimal taste quality to the consumer (Kader, 1996).

The influence of greenhouse growing conditions on product quality has been recently reviewed (Schnitzler and Gruda, 2002). Controlled stressful conditions can even be positive if, for example, they improve fruit quality (Gary, 2002).

The quality attributes of vegetables vary depending on the related species. From the quality point of view, some crops, like cucumber, whose keeping quality is the most important quality aspect (Welles, 1999) are relatively simple, but others like tomato are much more complicated. Several reviews of tomato fruit quality have been published (e.g. Hobson, 1995; Adams and Ho, 1995 ; Ho, 1995; Dorais et al., 2001).

In Europe, quality norms for fruit and vegetables are generally based on external quality and critical concentrations of pesticides and nitrate (Schnitzler and Gruda, 2002).

The future is on quality, but it must be a profitable quality, with benefits higher than costs (Herregods, 2000). The setting up of integral quality management systems appears as a clear priority, in order to emphasize the quality and differentiation strategies for the future of greenhouse production (Taragola and van Lierde, 2000). Including in the contract detail protocols, to be followed by growers for the sustainable production of safe and high quality vegetables, is a common practice in contract-based production between supermarket chains and large producers or cooperatives in Spain.

Markets

The challenge to supply seasonal, perishable products of high quality year-round has favoured international trade (Cook, 1999). In the “Mediterranean greenhouse agrosystem” both domestic and export market-focussed production coexist, in different degrees of importance depending on the country, and normally the export market requirements prevail when determining the qualities to grow, as the domestic market is often used as the destination for second quality commodities.

As compared with the Mediterranean area, Dutch agribusiness have built up a strong position on the West European market for fresh vegetables, specially in West Germany (Verhaegh and de Groot, 2000), one of the principal destinations of the Mediterranean export produce. The Dutch have recently strengthened their competitiveness in tomatoes by a strong growth of truss and cherry tomatoes (Verhaegh and de Groot, 2000) and with a range of other sizes (Hobson, 1995), diversifying their production within the same consumer-known species, as the introduction of completely new vegetables into the market seems much more difficult (Castilla, 2002; La Malfa and Leonardi, 2001). A similar trend appears in the Mediterranean area, especially in Italy (La Malfa and Leonardi, 2001) and Spain.

Horticultural products have to be produced safely even within socially accepted labour conditions (van Uffelen et al., 2000) and way of production (Ammerlaan et al., 2000). The traceabilitiy of the produce is becoming a necessity in order to provide the consumer with the required security about the way of producing. Growers have to produce their high quality products in an environment-conscious, labour-safe and hygienic way and be able to demonstrate this, to meet the customer’s demands (van Uffelen et al., 2000).

As stated by Tognoni and Serra (2002), strong competition for price and quality is expected in global standardized products (especially in the least refined ones), that can be produced in simple greenhouses, in emerging countries.

Though the ideal of “natural“ production methods, from the point of view of the consumer, is far away from greenhouse production (Larsen and Buwalda, 1998; Schnitzler and Gruda, 2002), the general image of the greenhouse as a “clean” and environmental-friendly way of production is being promoted, especially in the north of Europe.

Diversification

The diversification of greenhouse production is characterised by new presentations of established products (Castilla, 2002) rather than by new crops that require research and promotion in the market (La Malfa and Leonardi, 2001). New presentations of established crops include variations of the colour, shape or size of crops already cultivated, as well as quality labels, such as organic or eco-labels. Relevant examples of diversification are the cherry and cluster tomatoes, that reach 60% of total greenhouse tomato production in Italy (La Malfa and Leonardi, 2001) and of “baby” vegetables (Castilla, 2002). The use of transgenic cultivars, that can reduce the use of chemicals, contributing to improve the environmental sustainability, finds strong suspicion in the consumers (Castilla, 2002).

FINAL REMARKS

Production costs, product quality and environmental impact are the prevailing problems to solve in the greenhouse industry of mild winter climate areas (La Malfa and Leonardi, 2001).

The globalization of the markets has increased the competitiveness, highlighting the need for increased quality of greenhouse produce, through better climate control. An economic compromise between the higher investment costs of improved, better equipped greenhouses and their agronomic performances is required, in order to produce proper quality commodities at competitive levels. The transportation costs to distant markets in export focused production limit the competitiveness of the produce.

Growers education and training appear as a basic point, as the cultural level of the growers can be a limiting factor to improving the technological level of the greenhouses in mild winter climate areas (Baille, 2001). Great effort is required to obtain technical and economical knowledge relating crop response in greenhouse technology.

The demands of the market for healthy, safe and high quality products will be increasingly important in determining production strategies in the future. Quality and differentiation strategies are a clear priority for competitiveness.

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Tables

Table 1. Conventional tomato, sweet pepper (California type) and cucumber costs, for the best greenhouse growers in the Netherlands and Spain (1996). Climatised glasshouse in the Netherlands and plastichouse in Spain. The integral cost price are referred to the German market (Frankfort). Onetime used boxes.

Crop	Country	Yield	Cost (Euros/kg)	
		(kg/m^2)	Production	Market
Tomato	Spain	18-20	0.26-0.27[1]	0.53-0.62
Tomato	Netherlands	58-60	0.55[2]	0.73
Pepper autumn-winter supply	Spain	6.2-6.6	0.52-0.57	0.94-0.98
Pepper spring-summer supply	Spain	8.0-12.0	0.29-0.30	0.70-0.71
Pepper	Netherlands	23.0-27.0	1.18	1.50
Cucumber autumn-winter supply	Spain	9.5-12.5	0.20-0.23	0.49-0.52
Cucumber	Netherlands	65.0	0.49	0.65

[1] sorting excluded; [2] sorting included (Verhaegh, 1988; Verhaegh and de Groot, 2000).

Table 2. Estimated costs of greenhouse conventional tomato in Morocco (Agadir) in the typical export cycles to the European Union. The integral cost prices are referred to the French market (Perpignan). The production cycles are adapted to the export calendars.

Yield (kg/m^2)	Cost (Euros/kg)	
	Production	Market (Perpignan)
6.0	0.23-0.24	0.66-0.69
11.0	0.15-0.16	0.58-0.61

(Source: Calatrava J. Project CICYT-SEC-94-0391. Unpublished data).

Table 3. Composition of the variable costs of greenhouse conventional tomato in Almeria (adapted from Calatrava-Requena et al., 2001) and of beef tomato in Belgium (adapted from Benoit 1990; 2002; personal communication). Yields of 14 kg/m^2 (Spain) and 55 kg/m^2 (Belgium).

	Spain		Belgium	
	Euros/m^2	%	Euros/m^2	%
Natural gas (heating + CO_2)	-		8.80	35.0
Salaries	0.92	46.0	10.91	43.4

Plant material	0.17	8.5	2.00	8.0
Fertilizers+Pest control	0.65	32.5	1.37	5.4
Water	0.13	6.5	-	
Others	0.13	6.5	2.06	8.2
Total	2.00	100	25.14	100

Table 4. Average greenhouse structure construction costs in the south of Spain (taxes and price of the land are not included). Costs are calculated for 1 ha minimum area. Plastic film cladding is included.

Greenhouse type	Euros/m^2
Low roof slope structure (old “parral type”)	6.0
High roof slope structure (new “parral type”) with roof vents (multispan)	8.9
Arched shaped multispan with roof vents	13.8

Table 5. Structure and equipments costs for the high roof slope greenhouse (new “parral type”, Table 4) in the south of Spain. (taxes and price of the land are not included). Costs are calculated for 1 ha minimum area. Computerised climate and fertirrigation controls are not included.

	Euros/m^2
Structure	8.9
Fans (only mixing and removing)	0.9
Fogging system (low pressure)	1.5
Heating system (hot air)	2.7
Total	14.0

Table 6. Structure and equipment costs for the arched shaped multispan greenhouse (with roof vents) in the south of Spain. Costs are calculated for 1 ha minimum area. Computerised climate and fertirrigation controls are not included.

	Euros/m^2
Structure	13.8
Fans (only mixing and removing)	0.9
Fogging system (high pressure)	4.5
Heating (steel tube and CO_2 injection)	10.8
Shading-thermal screen	4.5
Total	34.5