

Trends in the adoption of greenhouse technology in mediterranean horticultural farms

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1. Introduction

Fruit and vegetable cropping is of utmost importance in Spain due to the high production levels and the value of exports. Although exports of certain outdoor horticultural species such as lettuce, cauliflower and cabbage (with a total of 897,245 tons) are significant at the national level, the largest share is represented by greenhouse crops (MAPA, 2007).

As regards the main crops, if we consider the three most important growing areas in Spain, which include the provinces of Almería, Murcia and Alicante, we find a production of 3,486,256 tonnes (53% of the national production) in a relatively small area which covers 53,735 ha. Eighty-one per cent of this area corresponds to protected crops, mostly under greenhouse, and only 19% to outdoor planting.

The use of greenhouses as the main growing method is related to the fact that the crops are more easily protected against viruses and other diseases and moreover, there are other technical and commercial characteristics which entail considerable

Abstract

There is a clear need to raise the level of greenhouse technology if we are to maintain the competitive position of the Spanish horticultural sector, as shown by the analysis made in this study. This work takes into account the data resulting from a stratified random sampling survey of 242 greenhouses for fruit/vegetable growing in southern Alicante, Murcia and the western area of Almería. Based on the data collected and by applying univariate and bivariate statistical analyses, we aim to determine the characteristics of the most fully-equipped greenhouse on each farm and the business trends in technology application. The results indicate that investments in technology are progressing slowly; the level of technology use for irrigation and fertigation is high whereas the development of climate control technology is still limited. While 22% of the farms surveyed use soilless cropping systems, with highly acceptable results, in only 6% of the farms the greenhouses reach a high technology level.

Keywords: Competitive position, greenhouse, horticultural farm, innovation technology, soilless cropping systems.

Résumé

A l'heure actuelle, il est sans aucun doute nécessaire d'élever le niveau technologique des serres afin de maintenir la compétitivité du secteur horticole en Espagne comme en témoigne l'analyse réalisée dans le cadre de cette étude. Les données utilisées ont été tirées d'une enquête menée par échantillonnage aléatoire stratifié sur 242 serres, produisant des fruits et légumes, dans le sud d'Alicante, en Murcie et dans l'ouest d'Almería.

En s'appuyant sur les informations acquises et les résultats d'une analyse statistique, univariée et bivariée, il a été possible de déterminer les caractéristiques de la serre la mieux équipée dans chaque exploitation et les tendances au niveau de chaque entreprise en ce qui concerne l'adoption des technologies. Les résultats obtenus montrent une évolution lente des investissements technologiques; nous observons un bon niveau technologique relativement à l'irrigation et la fertigation alors que l'utilisation des systèmes de climatisation reste encore insuffisante. Vingt-deux pour cent des fermes analysées ont introduit le système de culture hors sol, avec des résultats satisfaisants. En revanche, seulement 6% des fermes possèdent des serres avec un niveau technologique élevé.

Mots-clés: Compétitivité, serre, fermes horticolas, technologies innovantes, culture hors sol.

advantages in terms of quantity, quality and production calendar compared to outdoor production.

Intensive production in the horticultural sector has increased in the aforementioned areas over the last four decades, and currently greenhouse production is a key factor to competitiveness, which is based on:

- A lower-cost production compared to the horticultural greenhouses located north of the Pyrenees, which are more energy dependent.

- An efficient marketing network, starting from commodity or produce exchange and agricultural cooperatives, in addition to large companies with their own production. Sales are facilitated by Spain's proximity to the European markets, which allows for quick and easy direct delivery of refrigerated products to supermarkets by trucks.

- The availability of unskilled labour required for this type of work.

At present horticultural production and trade are greatly affected from the economic, environmental and food quality and safety point of view by:

- The level of market supply, with the risk of saturation and price decline. Mass distribution dominates in the retail area, which has reached high levels of market concentration and control, with the major groups reaching a rate of 60-70%. Overall, wholesale retailers enjoy a status of oligop-

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oly, given the oversupply, and they impose strict quality standards to suppliers, which often coincide with a sharp reduction in the price charged. Moreover, production takes place mainly on the farm with high production costs.

- The European Community Agricultural Policy is strongly oriented towards the environment and biodiversity; furthermore, there is strong consumer awareness of product health-related issues, especially concerning pesticide residues. As a result the concept of quality has considerably broadened and is now all-encompassing, including morphological and organoleptic properties, healthiness, environmentally-friendly production processes, hygiene and safety of workers, and all this guaranteed by a traceability system.

After the 1990s, food surpluses dramatically increased in the EU and at the same time, there was a growing trend in favor of environmental protection and sustainability. Agriculture is currently subjected to a highly critical analysis and blamed for its adverse effects on the environment. Consequently, some forums have highlighted the need to attain sustainable agriculture (European Community Commission, 2003). Therefore, when assessing agricultural activities, the European policies seek to embrace the goals of competitiveness and environmental protection, despite the fact that they seem clashing with each other.

In the present international context, the effects of globalization are very clear, and the establishment of a free-trade area between the EU and the Mediterranean countries is unavoidable (García-Azcárate and Mastrostefano, 2006). This will have a serious impact on the agricultural sectors of both groups of countries.

In the short and medium run, production and trade of horticultural products will be linked to:

- The Euro-Mediterranean Agreement.
- The downward trend of income earned by producers.
- Traceability, which has become mandatory since 2005.
- The very irregular application of norms on maximum residue limits (MRLs) in the EU, with a law setting the limits which are not always fully complied with by some food chains.

The conditions and concepts described above contribute to the productive and commercial status of each crop, conferring a more or less steady competitive position.

factors affect competitiveness and can be incorporated into an economic analysis on this issue. Among others we

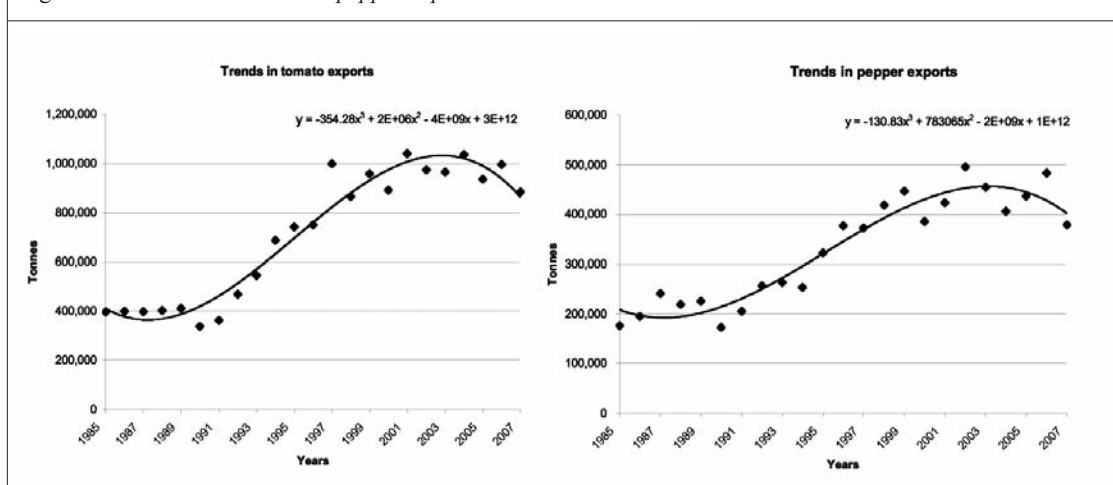
may cite: prices and price trends, quality, business services, specialization, product differentiation, promotion and technology (Chebil and Britz, 1999). The production and marketing costs play an important role in business, especially in view of the initial investment incentives, but they are not the only reason for competitiveness (Barceló, 1987).

A brief analysis has been carried out to assess the level of competitiveness, considering only the export and price trends. In this time of increasing globalization, foreign trade figures and prices indicate the strengths or weaknesses of a sector.

From 1990 to 1998 a very sharp increase (2.5 times) was recorded for exports; in contrast, from 1998 to 2004 the growth rate equalled 2.15% per year, and from 2004 to 2007 exports dropped to 2.4% annually (MARM, 2008).

A further investigation has been conducted on a series of export figures and prices for tomatoes and peppers intended for fresh consumption, since these two crops are among the most important horticultural crops. Export trends for both products are reported in Figure 1 which also indicates that, in terms of competitiveness, Spain suffers from saturation in the mature markets as it occurs in other major European consumer countries. There is still scope for expansion into new markets but, seemingly, absorption capacities are low.

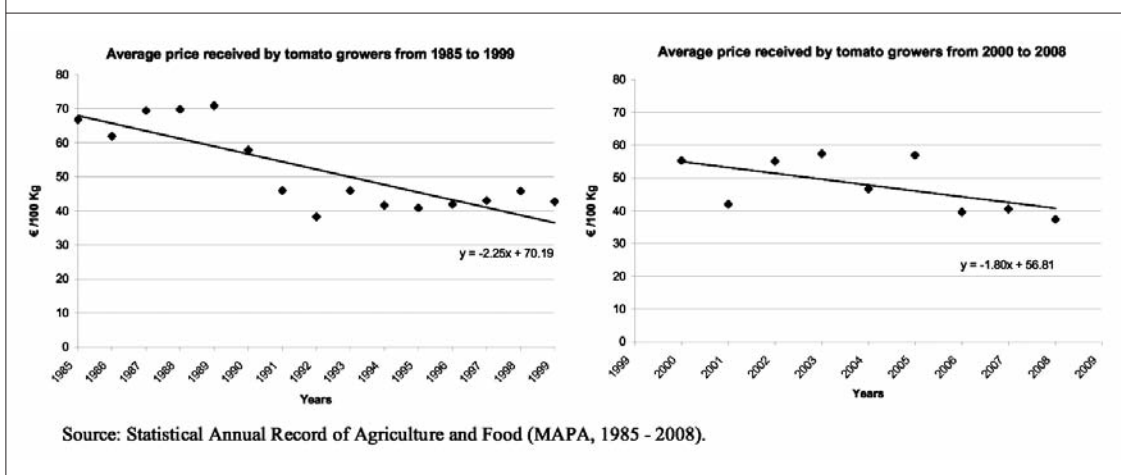
Figure 1 – Trends in tomato and pepper exports.



National average figures, updated to 2008, have been considered to estimate trends in tomato prices, and Figure 2 has been drawn up accordingly. The analysis was performed on the same data set and shows the price trends for two periods (1985-1999 and 2000-2008). In the first period, the trend indicates a slope with a very sharp decrease, typical of a product that started off at high levels, while in the second the slope drops more gently and, except for special types of tomatoes, it continues to drop steadily.

In the first section, given the strong downward trend, we can accept that profits were higher than normal but in the last section profits have dropped or even disappeared in many cases.

Figure 2 – Average prices received by tomato growers.



A similar price analysis was applied to peppers, within the same data set, and an upward trend was observed between 1985 and 1998, which dropped slightly between 1999 and 2007. The latter figures may indicate that there are no serious problems of oversupply, but markets are beginning to reach a saturation point.

Hence one might conclude that the competitive position is not seriously threatened but at same time it does not show any clear advantage or a growing expansion trend.

In addition to these conclusions on competitiveness, considering the export and price trends, one must also bear in mind that the immediate liberalization of markets and increased trade with the EU will favour an improved productivity (Hassine-Belghith and Ayed-Mouelhi, 2007). However, in intensive vegetable cropping, strong investments are required to raise the equipment and technology standards in the greenhouse in order to remain competitive.

Therefore the present study will aim to:

- Assess, the current state of technology used based on the greenhouse type and components, and the needs to adopt new technology.

- Determine the farm structural features and analyze the business characteristics regarding the use of technology in the light of the future needs.

2. Information and Methodology

Horticultural holdings with greenhouses are the main sources of information and the focus of the present work. The most important and representative areas selected to carry out this study are located to the South of Alicante, Campo de Cartagena and Valle del Guadalentín Murcia and the western region of Almería.

To describe the current state of technology use in the greenhouses and assess the business characteristics considered to be most relevant to investment and production techniques, and also to formulate working hypotheses, the following information sources have been used:

- Technical and economic documents and literature.

- Notes taken directly from inspections in the reference areas.

- Interviews conducted with companies, agricultural cooperatives and technicians, located in the area under investigation.

Once information was available from the study areas, questionnaires were drawn up and administered to lay the foundations of this work and try to provide empirical solutions.

From the extensive literature on this topic, we initially focused on the publication by Navarro (2001), which gives a historical overview of the steps characterizing the development of greenhouses in Almería. A considerable change has taken place in both greenhouse structures and materials and growing techniques, with special emphasis on plant protection.

In the early stages, protected production was based on the introduction of low-cost greenhouses, mostly of the parral type, which led to the very rapid expansion of the covered growing surface (Fernández-Zamudio et al., 2006). The first types of parral greenhouses were merely an adaptation of the old-fashioned arbor structures, used in Almería, for growing table grapes to support the plastic covering. Today this flat-roofed greenhouse still covers 27% of the total area, and in some ways is the most typically identified with the Mediterranean greenhouse type; however, it is undergoing major restructuring. In fact, in greenhouses that are less than nine years old the proportion of flat structure types has fallen while the so-called «de raspa y amagado», asymmetric and multi-tunnel predominates (Molina et al., 2003).

Based on the structural elements, the simplest and cheapest greenhouses are those using wooden support material. These greenhouses are on average 14 years old, with up to 13% of the greenhouses more than 15 years old falling in the province of Almería (Fernández and Pérez, 2004).

2.1. Necessary technology developments

Along with the structure and covering materials, the greenhouse geometry and height have also greatly changed, with two-slope roof greenhouses (symmetric and asymmetric) replacing the flat-roofed ones, since the latter have a limited production in autumn and winter due to a low solar radiation transmissivity (Castilla and López-Gálvez, 1994).

Although the proportion of flat parral type has dropped and greenhouses have been modified, with a move towards higher buildings with overhead ventilation, overall about two thirds of the total area has zero to a low number of elements for climate control, frequently incorporating manually opened windows and low levels of mechanization. Only

one third has an acceptable technological level. The proportion of technological provisions in multi-tunnel greenhouses is also low.

An increase in yield and quality requires better equipped and improved programming of the climate control elements. In addition to the necessary development of structures and equipment, special attention must be paid to the introduction of soilless cropping systems, together with all the technological improvements involved in its implementation.

2.2. Survey on technology adoption

To perform this study, a sample size will be determined from the set of farms in the study areas, for which a questionnaire shall be answered individually.

Once information had been collected from the three study areas and considering the needs for the technological improvement highlighted, we went on drawing up the questionnaire. In accordance with the objectives set, the following basic issues were identified:

First, to find out some of the structural characteristics of the farm which were considered most closely related to technology and types of greenhouses.

As planned, an analysis of the current state of technology was made focusing on its development. As regards the technology adopted in the greenhouses, we took the greenhouse with the highest level of technology on each farm as reference.

To analyze the adoption of technology, the evaluation of the growers' attitudes to adopt soilless cropping systems seemed to be important, since this is the most advanced growing method in current developments.

2.2.1. Sample representativeness

The sampling method applied is a stratified random type, with strata corresponding to Campo de Cartagena, Valle del Guadalentín (both belonging to Murcia) and El Ejido (Almería).

The population size corresponds to 6,917 greenhouse owners (3,714 owners in the area of El Ejido, 1,888 in Campo de Cartagena and 1,314 in the Valle de Guadalentín area), and the sample size calculated proportionally is:

$$n = \frac{N p q k^2}{e^2 (N - 1) + p q k^2}$$

Where:

n = sample size.

N = population size.

k = coefficient depending on the resulting confidence level.

p = percentage of population presenting the feature.

q = percentage of population with no property ($1-p$).

e = maximum permissible error for a confidence level of 95%.

We determined the sample size for a 95% confidence level and a maximum permissible error of $\pm 6\%$, yielding a

sample size of 257 surveys, and once the invalid ones had been rejected, there were finally 242, for which the sampling error was $\pm 6.2\%$.

It should be noticed that the maximum permissible error of $\pm 6.2\%$ occurs when the proportion estimate is 50%, *i.e.*, $p = q = 0.5$, this being the worst scenario. The surveys were distributed per stratum as follows: Campo de Cartagena represents 27.3% of the sample and Valle de Guadalentín 19.0%, which once added give 112 surveys, and El Ejido representing 53.7% of the total, with 130 surveys.

2.2.2. Data collection and processing

The data collection method was by personal and individual interviews addressed to the greenhouse owners, chosen at random from the total list of owners. A pilot questionnaire had previously been administered to 10 farmers. The 257 interviews were conducted by interviewers who were experts in the production of these areas.

Once the fieldwork had been completed in the first half of 2007, and the interview questionnaires had been checked to test their validity and possible correction, we went on to code responses, which gave rise to qualitative and quantitative variables. The data obtained were processed with SPSS 13.0 software and Statgraphics Plus 5.1.

3. Result analysis

Data processing focused mainly on the univariate analysis to reflect the farms and greenhouses characteristics, the results of the variables related to factors affecting adoption and innovation procedures and environmental issues.

By implementing the bivariate analysis we tried to study the possible association between pairs of variables that were considered of utmost interest.

3.1. Results of the univariate analysis

Below are the results obtained by applying the calculus program to the variables corresponding to the characteristics of the farms and greenhouses included in the questionnaire.

3.1.1. Surface area

The average greenhouse surface area per farm is 26,560.12 m². In 25.6% of the cases, almost all located in the province of Murcia, farms have also outdoor growing areas covering on average 7.57 ha.

For greenhouses using soil cropping, the average land area is 23,666.44 m², while for soilless cropping systems it reaches 21,714.04 m². The average area of basic parral is 15,348.91 m² and for improved parral it is 19,675.13 m² while multi-tunnel structures cover 13,487.10 m². Concerning the best equipped greenhouse in each of the holdings, the average size is 9,888 m².

In general, the greenhouse area per farm has grown over time in line with the demands for a higher income on family farms, which represent the majority. This is a potential provided by specialization in intensive horticultural crops.

3.1.2. Farm owners and characteristics of the labour force

The average age of owners is 42 years, and the corresponding frequency distribution is shown in Figure 4.a. This feature is important, and very different from that found in other agricultural sectors in Spain.

Figure 3b shows a comparison, representing the age intervals of the individual farmers and the number of owners per interval, according to the Survey on the structure of agricultural holdings (2007) (INE, 2008). That the age distribution of farm owners with greenhouses (Figure 3a) form a Gaussian curve around the average value of 42, while in Figure 3b, the age of farm owners nationwide displays a minimum in the interval corresponding to the age under 25 years, with a growth in age increase, and finally a maximum with very high figures corresponding to owners over 65. Therefore, one can infer that the population of farm owners with greenhouses is not affected by aging like other farm owners throughout Spain.

competitiveness of productive systems under greenhouse.

Regarding crop species, there is a considerable differentiation according to the productive areas; hence, there is strong specialization in pepper growing in Campo de Cartagena. A similar situation occurs in the region of Valle del Guadalentín with tomato growing, where the towns of Mazarrón and Águilas are the main centers. In Almería, the large area of protected cultivation not only permits, but rather demands, greater crop diversification and, although the pepper and tomato take the largest share, there is also a large supply of the other products cited above.

The marketing models adopted in the production areas, and their development, have been instrumental to promoting intensive horticulture worldwide. In the early stages, on-farm sale dominated and wholesalers played an important role. Today the trend encompasses two supply chain models, agricultural cooperatives and produce exchange (small markets with auctions), which differ greatly, but have the advantage of being complementary to each other and encouraging competitiveness and competition.

Some 58.3% of the produce is sold via agricultural cooperatives and 37.6% via produce exchange, while the wholesalers trade only 1.2% directly, probably because they buy the product from produce exchange or agricultural cooperatives.

3.1.3. Greenhouse characteristics

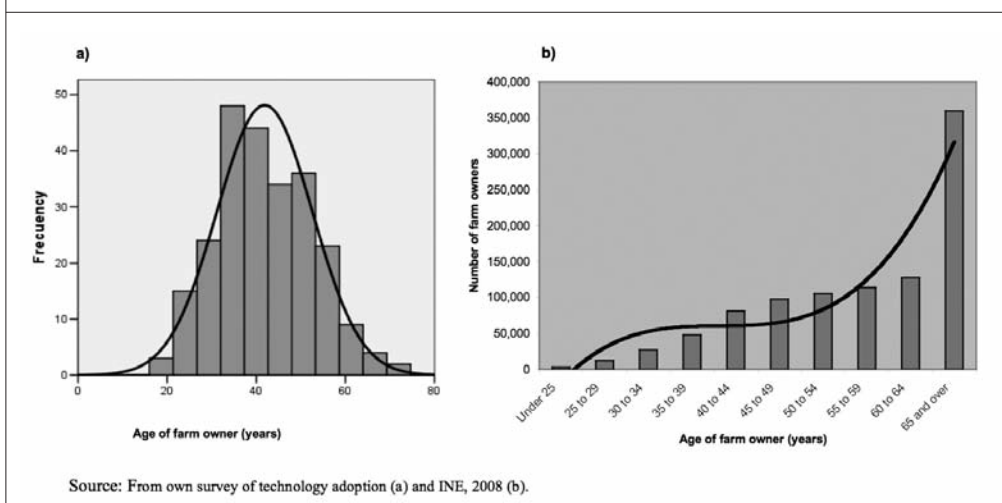
As this study is primarily focused on the adoption of technology, information on the technological level will consider the best-equipped greenhouses on each farm as a reference.

The most common type of structure is the metal one with steel profiles (92.6%), of which 14.5% are provided with motorized opening windows.

As regards the greenhouse type, the parral largely dominates and the oldest one is the flat-roofed type. In the last 20 years it has been improved by increasing its height, adopting symmetrical or asymmetrical shapes and enhancing the surface ventilation, especially overhead. Moreover, 11.2% of the greenhouses are multi-tunnel, which means higher quality structures, whose components are designed to improve the functioning.

Most greenhouses are fully covered with flexible plastic. The addition of PVC fronting is considered an improvement and is applied in 10% of the greenhouses. At the same time 4.6% of the greenhouses were found to use mesh covering, which allows considerable saving – although protection is lower with almost no effect on temperature (García-Martínez et al., 2008).

Figure 3 – Age of the owners of farms with greenhouses (a) and owners of agricultural holdings (b).



Another feature that differentiates intensive horticultural activity from other agricultural activities is the percentage of part-time work for farm owners, which is very low, just 4.5%. In contrast other owners are full-time engaged, thus indicating a high rate of appropriate size for most farms.

Succession is assured for 31.1% of the farmers, a rate that has declined in recent years, also due to the steady, albeit slow, decline in farm profitability and the greater importance and prestige parents give to academic training for their children.

In each holding, an average of two family members declared their full-time commitment, while an insignificant number reported part-time commitment.

Family labour, in the whole set of farm holdings, reached a rate of 8.2%, which means that most working hours, *i.e.* 92.8%, are provided by casual labour from outside the farm, mainly by immigrants. Availability of such a labour force has significantly influenced the wide distribution and

According to the data collected in the surveys, the implementation of irrigation technology is important. Here we should consider that the three study areas are extremely arid and thus it is indispensable to ensure proper water storage and efficient irrigation. Ninety per cent of the farms have irrigation reservoirs; 47.5% are provided with automatically programmed and regulated fertigation, while 15% of the facilities are fully computerized. In the early 1980s drip irrigation was largely developed and in the late 1990s the use of automated sprinkler heads was substantially increased.

Insect-proof netting is installed in almost 100% of the greenhouses, with the exception of those covered with mesh. Although mesh reduces ventilation and is an extra element in greenhouse management, it is considered essential for biological control, especially in recent years following the limitations on the use of insecticides, and the development of integrated production and organic farming.

For some agricultural operations, e.g. harvesting, the level of mechanization in 94% of the total sample, is quite low since only 3.8% of the farms are equipped with lift platforms. Moreover, a very low proportion of greenhouses have rails which facilitate a more efficient use of machinery.

Additionally, the greenhouses surveyed display a low level of climate control technology. Shading screens are installed in 8.7% of the total, 6.6% have interior shading mesh and 5.8% have external shading mesh. Only 6.2% utilize the misting system, an efficient technique for temperature regulation while 12% of the greenhouses are provided with destratification equipment. Eight point seven percent (8.7%) of the facilities are relatively fully equipped in terms of climate conditioning.

The low rate of technical solutions which facilitate climate control (netting, screens, misting and destratifiers) suggests that overall, greenhouse owners have not found clear and valuable economic reasons to spend on the above systems which should have a potential impact on the product quality and production calendar. On the other hand, whitewashing is a well-proven and widespread practice, despite its drawbacks.

Given its economic impact, both in terms of initial investments and fuel consumption, heating is not much used in horticulture. Of the whole sample surveyed, 7.4% of the greenhouses are heated by hot water while 5.4% apply hot air. All the hot-water facilities are used, or can be used, on a permanent basis, while air systems are usually used permanently by only 1.3%. When temperatures exceed 14° C, heating is applied only in 3.3% of the farms.

As for the cropping system, 77.7% of the greenhouses adopt soil cultivation, while 22.3% apply soilless culture.

3.1.4. Attitudes towards the implementation of soilless cropping systems

Of the farm owners surveyed, 72.3% believe that soilless culture is «uninteresting» and qualify it as «just another technique», whereas 27.7% consider it important or essential.

The advantages of soilless cropping systems, classified as «very important» by a high percentage of the farm owners, are the higher commercial quality of products (20.2%) and ease to apply irrigation, due to the availability of performing systems (19.1%).

he most important disadvantages indicated for soilless culture we found: «it is the most expensive of all», expressed by 53.3%, and «it seems very risky», expressed by 46.3%.

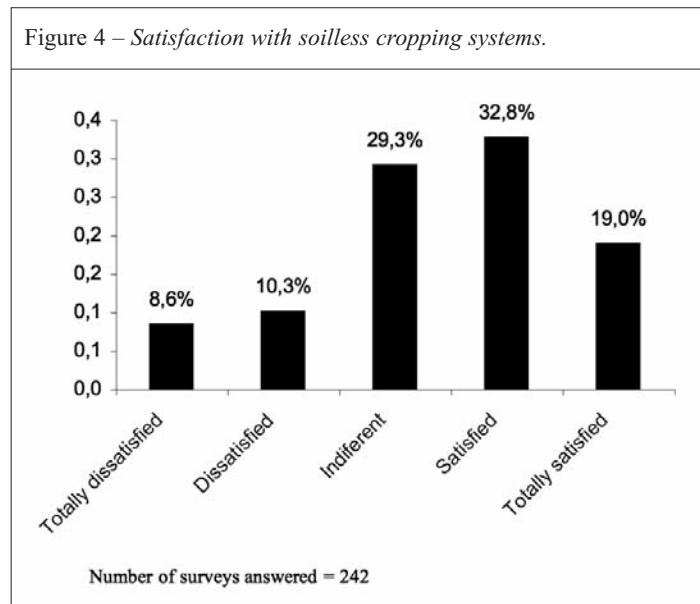
3.1.5. Factors affecting the innovation process

The farmers' main source of information about soilless cropping systems is represented by other farmers in 39.4% of the cases, and more directly, by relatives engaged in agriculture.

When technical advice is needed to solve some problems, the prevailing option is resorting to technicians from the agricultural cooperative. More than half of the total number of farmers read some kind of agricultural publications, mostly in the form of magazines.

Farmers who apply the soilless method have expressed their satisfaction with the following percentage distribution:

Figure 4 – Satisfaction with soilless cropping systems.



The results in Figure 4 sum up the opinions expressed by farmers on their satisfaction with soilless culture. These results indicate that the opinion is very favourable among farm owners, since negative or unfavorable answers are given only in 19.0% of the cases.

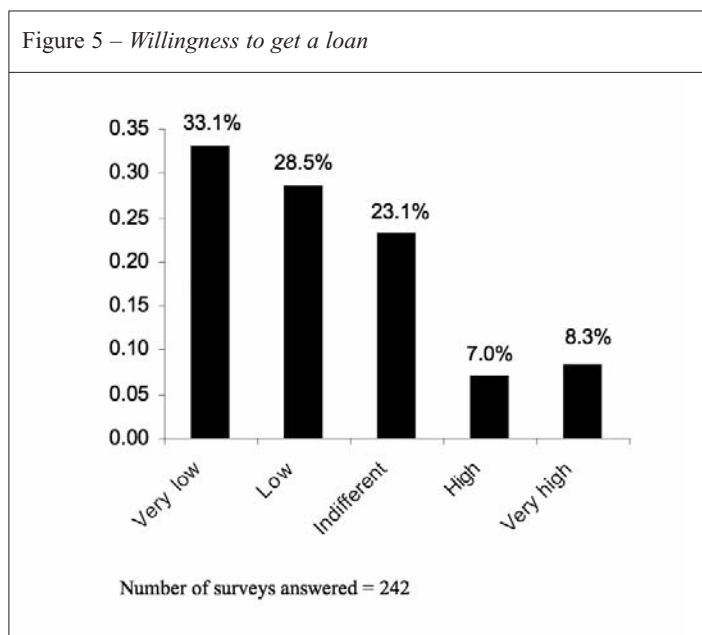
Concerning the main problems related to soilless crop production, the high investment cost is considered to be very important by 42.1% of the respondents; the management difficulties by 14.9%; the fear that any trouble might lead to the loss of the whole harvest by 43%; and, the need for extremely prompt technical assistance by 15.7%.

It is noteworthy that the management difficulties are given less emphasis, thus indicating that the level of information is

good, and that farm owners do not give undue importance to the need for prompt technical assistance, partly because both companies and technical staff are available. Greater importance is directed to problems related to high investment costs and the risk of losing a harvest due to errors or deficiencies.

3.1.6. Financing

Attitudes towards accepting funding from third parties are distributed as shown in Figure 5.



Farmers who state they are quite or very unwilling to get loans represent 61.6%, while 23.1% claim they are indifferent and only 15.3% reveal a high or very high willingness to get a loan. Overall there seems to be a relatively favorable business attitude towards accepting the risks of contracting a debt, because 38.4% of the respondents do not demonstrate a negative attitude.

Table 1 – Variables analyzed and data included in the test of independence.

Pairs of variables chosen	χ^2	D.f.	P-value
1. Willingness to innovate the greenhouses – Presence of successors	8.10	2	0.017
2. Willingness to innovate the greenhouse – Greenhouse type	2.47	2	0.291
3. Willingness to innovate the greenhouse – Farmer's age	5.99	4	0.200
4. Willingness to contract a debt – Farmer's age	11.60	8	0.170
5. Soilless cropping systems – Farmer's age	5.18	2	0.075
6. Installation of shading screens – Region	44.32	2	0.000
7. Computerized window opening – Region	70.14	2	0.000
8. Main market outlets – Region	7.65	4	0.105

Source: Own data.

As for the funding sources preferred by the farm owners, Savings Banks or Building or Rural Savings Societies have been chosen by 81.4% of the owners, followed at a considerable distance by the option of using their own income, chosen by 56.6% of owners.

3.2. Results of the bivariate analysis

3.2.1. Test of independence

Statistic χ^2 was used to analyze whether a relationship exists between the row and column variables in a contingency table. The pairs of variables chosen are listed in Table 1 along with the results of the test of independence:

Pair 1: Findings show that 77.87% of the farmers who are unwilling to make changes have no successors. In contrast, for those who have successors, the percentage of those who do not want to make changes drops to 22.13%. The p-value for statistic χ^2 proved to be significant. Therefore, we reject the null hypothesis that there is independence between the two qualitative variables under investigation.

The number of farms without generation take-over is more than double compared to those with a successor; however, the difference between the rate of those without a successor and those with, is lower for those who intend to innovate their greenhouses.

Pair 2: The test did not prove to be significant ($p > 0.05$) and therefore one cannot confirm that the willingness to innovate the greenhouses is more or less associated with the greenhouse type, which is in line with the remark that the most widespread greenhouse system is undoubtedly the parral with sand-mulched soil, a type of greenhouse that the farm owners are unwilling to change.

Pair 3: It is clear that the willingness to innovate the greenhouse does not depend on age, as the test for independence is not significant.

Pairs 4 and 5: There is some analogy or correspondence between the two cases. If one relates both the willingness to innovate the greenhouse and the willingness to contract a debt, with the age variable, it can be demonstrated that this variable is not decisive.

Pair 6: The highest contribution to the chi-square is found where the use of shading screens corresponds in the table to the area of Campo de Cartagena which, according to the results, includes most of these types of climate-control solutions.

The p-value for the statistic χ^2 proved to be highly significant. Therefore, we reject the null hypothesis that there is independence between these two variables.

Pair 7: The p-value for the statistic χ^2 proved to be highly significant. Therefore, we reject the null hypothesis that independence exists between these two variables, accepting the existence of significant associations between the levels of the two qualitative variables under investigation.

As in the case of the shading screens, it seems unnecessary to apply the test as virtually all greenhouses with computerized vent opening are found in a particular area, *i.e.* Campo de Cartagena.

Pair 8: Verification of the relationship between the variables corresponding to the main trade outlet and the production areas in which they are located would indicate that this relationship exists at a 10% significance level. Produce exchange is more often reported from El Ejido and the Guadalentín Valley while the agricultural cooperative trade outlet predominates in Campo de Cartagena.

However, rather than considering the percentage for each single case, it is important to underline that both produce exchange and agricultural cooperatives coexist in all the three regions (thus including agrarian transformation societies). This choice of the trade outlet is of great interest if one considers the difference in the way they operate.

In the case of agricultural cooperatives, the members are paid their settlement as a difference between the price paid by the retail trading entity of destination and the marketing and transportation costs. The product is sorted and packed in the agricultural cooperative warehouse and the payment is deferred for a variable time. They usually allocate a larger share of products to exports.

The produce exchange means greater freedom for the producer, as the sale and the resulting income are determined by daily auctions, and the farmer can accept the price or withdraw the goods. The product has to be taken there every morning after a preliminary classification and preparation and the payment is immediate and guaranteed.

The high level of product exchange is very positive for the whole marketing process in the horticultural sector of these areas as it contributes to competition and price transparency.

4. Conclusions

– The technological level of horticultural production in the Spanish greenhouses is related to the following:

- the individual characteristics or the features of the holding including the farm owner's age, whether or not the farm has a successor, the farm size and the technological level at which the farmer aims;

- external conditions like the markets, the price, the globalization process, the direct competition (particularly by the Mediterranean countries), the quality changes and the product health and safety demanded by consumers. All this has an impact on the pricing perspectives determined by trade opportunities, and therefore on the owner's willingness to invest;

- as regards the technology available, it should be noticed that in the different areas there are many suppliers *i.e.* specialized companies, that can provide technical services for the mechanical components, for assembling and maintaining, as well as companies offering technical consultancy and assistance.

– The literature on the state of technological development would suggest that great advances were made in the past; in contrast, as demonstrated by the results of this study, innovation is today brought in at a slower pace. In fact, there still exists a certain number of farms which have not even gone beyond the level of wooden structures.

– The percentage of farms with technologically advanced and fully-equipped greenhouses accounts for only 6%. This is the case of greenhouses which have a properly sized structure, are provided with permanent heating, climate control, automatic irrigation and fertigation systems and other pieces of equipment or characteristics that are also considered important. The traditional parral type is found on 25% of the farms and the modified parral type mostly prevails, which often incorporates more technology, but maintains a low installation cost. Alternatively said, the lowest technology levels are recorded on most of the sampled farms, thus confirming the slow pace of innovation.

– It seems clear that the level of investment is not high for climate control. However climate control is really necessary because it has a decisive effect on production quantity and, above all, quality.

– With regard to greenhouse mechanization (moveable apparatus and auxiliary treatment and harvesting equipment), taking into account the results of the total set of farms, a relatively low level can be highlighted. Very little use is made of rails, lifting platforms and automated treatments with plant protection products. Admittedly, increasing mechanization up to reach a high level of available stock of moveable apparatus is a long way off, although investments made in this sector would not need to be heavy.

– Insect-proof netting for biological pest control is fundamental and due to its efficiency it is extensively used in all the greenhouses, with a very positive effect on crop development, but also on the product image.

– Since water is a limiting factor we find that irrigation and fertigation are applied where most investments are meant to enhance the technology level. This is the area of technology implementation most preferred by farmers.

– Sand-mulching, a cropping method widely found in the greenhouses of Almería, is a well-established production system, not only in terms of production features but also in terms of surface area and specialization. It is not usually applied in structures that are considered more comprehensive – nor in those provided with heating. Such a system is stable and resistant to change.

– Examining the attitudes of farm owners towards soil-less culture, it would appear that at present there is not much scope for further growth as only 27.7% of them consider this production system as important or essential; a figure that barely exceeds the percentage of farm owners who actually adopt it. To encourage the use of this technique by a larger number of farm owners, technology transfer should be promoted as nearly half the farm-owners consider this system to be «just another technique». A very positive as-

pect for the future spread of soilless culture is the opinion expressed by the farmers who apply this method, which prove clearly successful in 51% and indifferent, without rejection, in 29.3% of the cases.

– It is essential to raise the level of greenhouse technology in order to increase the competitiveness of Spanish intensive horticulture. In addition to greenhouse size and equipment, there is a very direct relationship between product quality and prices with soilless culture, heating, different integrated production models and, in recent years, organic production.

– The main investment problem encountered by farmers concerns the sharp difference between the simple types of greenhouses and those which are better equipped, which usually include: a metal structure measuring at least 4.5 meters in height on the side, shading screens, automatic irrigation and fertigation, hot-water heating system, misting and provision of computer equipment. This requires an investment of 45-60 euros/ m² while an investment of 9-15 euros/ m² may be sufficient for the simple types.

– Concerning the willingness to make business investments, there is a very favourable attitude towards the risk of getting a loan. The funding sources are primarily represented by banks and rural or savings banks. The option of using one's own resources is important and it concerns more than half of the owners, which indicates a high rate of farms with significant household savings. Rural banks play a very direct and intimate role, for both financial services and technical advice.

– Results did not appear to be favourable in terms of technological development, as answering the question about their willingness to innovate their greenhouses only 10% of the farm owners stated they were willing to make changes immediately, and 35% in the medium or long run, while half of them stated that they did not intend to make any improvement. These answers had a direct relationship with the presence of a successor, whereas there was no significant relationship with the farmer's age nor with the type of greenhouse available.

– The farmers' willingness to invest is particularly hampered by the price trends, which are considered the main cause of revenue decline per m² in the recent growing seasons. Although farming becomes more competitive by the use of new technology, the higher the investment, the lower the relative return on that investment.

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