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Characterization of technological levels in Mediterranean horticultural greenhouses

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Abstract

The technology existing in Spanish horticultural greenhouses is highly diverse; however, low levels predominate. Therefore urgent improvements and conversions are required to increase yields and quality to maintain competitive production. To define the equipment and investment required, it is necessary to establish the current levels of technology and the extent to which it is developing. To do so, information has been collected using a survey based on stratified random sampling in the three most important greenhouse horticultural areas in Spain: Almería, Murcia and Southern Alicante. Based on information from 242 farms, five groups of technological levels with a gradual variation in technology were identified by cluster analysis. Of the five groups, three relate to cultivation in soil and the other two to soilless culture. In this study, we have applied the test for independence in order to relate the levels obtained with certain relevant characteristics of the farm. The results display the usefulness of grouping the greenhouses by levels, and reveal which are the most characteristic components in level formation with their percentage distribution. Thus, current characteristics of technology, and its development, have been identified, and priority assigned to the different components.

Additional key words: cluster, horticultural systems, random sampling, technological development, test for independence.

Resumen

Caracterización de niveles tecnológicos en los invernaderos hortícolas mediterráneos

La tecnología de los invernaderos hortícolas españoles es muy variada, con predominio de los bajos niveles, por lo que es urgente su mejora y reconversión, para aumentar los rendimientos y la calidad y mantener la posición competitiva de las producciones. Para establecer las necesidades en inversiones y equipamiento es preciso conocer los niveles actuales de la tecnología y su grado de evolución, para lo cual se ha tomado información por encuesta basada en un muestreo aleatorio estratificado en las tres zonas españolas más importantes: Almería, Murcia y sur de Alicante. A partir de la información de 242 explotaciones se determinaron por análisis cluster cinco grupos con sus niveles tecnológicos y una variación gradual de la tecnología. De los cinco grupos, tres corresponden al cultivo en suelo y dos al cultivo en sustrato. A continuación, y con el fin de relacionar los niveles obtenidos con algunas características relevantes de la explotación, se aplicó el contraste de independencia. Los resultados han evidenciado la utilidad de la agrupación de los invernaderos por niveles, y qué elementos son más característicos en la formación de un nivel con su distribución porcentual. Se han determinado así las características actuales de la tecnología y, en su evolución, la prioridad que se asigna a los diversos componentes.

Palabras clave adicionales: contraste de independencia, cluster, evolución tecnológica, muestreo aleatorio, sistemas hortícolas.

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Introduction

Equipment and technology used in horticultural greenhouses vary greatly and are dependent on constant development. Clearly, the changes taking place in technology and since the 70s the rapid increase in the surface area covered by greenhouses have been facilitated by the use of plastics.

In Spain, large-scale greenhouse vegetable production first took place using very simple hand-made models, gradually emerging from field trials in the early 60s; however, out of season vegetable harvesting already took place on a small scale in the second half of the 19th century (García-Sanz, 1865). In this work, mention is made of forced cultivation by means of coverings, greenhouses and conservatories. Some of these buildings reached great perfection with the use of wood, steel and glass, and were sealed to insulate them from the outside in cold spells. In Spain, there were few such buildings due to the benign climate, whereas in England and United States they were important to obtain vegetables and flowers for London and New York markets.

Although there are greenhouses scattered throughout Spain, it is estimated that 73% of those pertaining to real farming systems are located in the most arid regions of Almería, Murcia and Alicante, whose analysis is included in this study.

A description of the technological developments in Almería greenhouses, including a chronological review (Navarro, 2001), highlights the work by the *Instituto Nacional de Colonización* (INC-National Colonization Institute) as the starting point of testing techniques of sand mulching in 1957 and the development of the first greenhouses built using plastic in the first half of the 60s. The 70s marks the consolidation and expansion of greenhouse cultivation.

In the early stages, protected crop production was based on the introduction of low-cost greenhouses, most were flat parral-type, which led to the rapid spread of the covered surface (Fernández-Zamudio *et al.*, 2006). This originated in the province of Almería, and was basically the rehabilitation of the old parral system used for table grapes.

According to the *Consejería de Agricultura y Pesca*-Agriculture and Fisheries Council (Junta de Andalucía, 2007) of Andalusia, the area of greenhouses in Almería was estimated at 26,800 hectares, of which the highest proportion corresponded to the symmetrical multispan parral (greenhouse backbone structures) which is currently the most frequently used (Fernández and Pérez, 2004). The proportion of the initial flat parral is decreasing; however, it still represents 27% of the surface cover in Almeria, and it should be noted that it has been the most closely identified with the Mediterranean type, but is undergoing a major restructuring, and its development, marked by technological requirements, it seems necessary and inevitable (Molina *et al.,* 2003).

The most commonly used material is galvanized steel, providing greater load resistance and finally aluminum alloy, which resists corrosion better but at a higher price and providing lower load support.

Plastics used as covering were initially a mere physical protection, but later have incorporated more qualities, like durability, elasticity, thermal and anti-drip properties to prevent internal condensation. In Mediterranean area there are also some greenhouses in which a mesh is used as an alternative to the plastic cover.

Along with the structural and covering materials, both the geometry and height have undergone change, and the double-pitch roofed greenhouses (symmetrical and asymmetrical) replaced the flat-roofed ones, because the latter limit production in autumn and winter because of low transmissivity of solar radiation (Castilla and López-Gálvez*,* 1994).

There is no such thing as a «more Mediterranean» kind of greenhouse; the reality is that each farm equips the greenhouse according to the characteristics of the originally chosen structure. Changes made to improve the technological level are continuous and by aggregating components they make the facilities more or less complete.

A comparison of production means and technology between Spanish and Dutch intensive horticulture reveals very different technological levels. In the Netherlands and Central Europe it is common to find the glass-Venlo greenhouse type, with high energy intake, trying to improve climate and cultivation, while in the Spanish Mediterranean, installations are used that require lower investments, with plastic covering and various structural options ranging from the simplest flat parral type to various degrees of change to achieve improved parral type, to the multi-tunnel type. The equipment is much lower level than in the Dutch greenhouses, and hence the level of climate control gives production results that are inferior in both quantity and quality.

The main advantage of the greenhouses in the Spanish Mediterranean regions has been their low cost and very low energy use. However, to maintain the competitive position of Spanish production it is necessary to improve the quality and yields, which requires raising the technological level of greenhouses, which is linked to a process of reflection and business decision-making depending on the characteristics of demand and prices. Existing facilities must be upgraded or converted to a great extent, when profitability drops due to price decrease (García-Martínez *et al.,* 2008). The current situation is highly dependent on the opening of markets, with is boosted by the Euro-Mediterranean Agreement, as it imposes the obligation of Spanish production to compete with other countries, especially in the Mediterranean, including Morocco, Egypt or Turkey, which have different socioeconomic characteristics and labor available at much lower prices. Spain should base their competitiveness on increasing investments and improving technology and quality.

Knowledge of the overall current state of equipment and technology is necessary both in political and in business decision-making to increase the efficiency of greenhouse production. Accordingly, this study poses the following objectives: i) to determine the levels of technology that can be considered by creating distinct groups of units with homogeneous traits, ii) to establish the degree of development of Mediterranean greenhouses, and how each technological level is defined depending on the characteristics of the structure and set of components that form it.

Methodology

Data collection

To carry out this study, the South of Alicante, Campo de Cartagena and Valle del Guadalentín in Murcia and Poniente de Almería have been chosen as the most important and representative regions. In the region of Campo de Cartagena and Southern Alicante there is a predominance of pepper crops, in Valle del Guadalentín there are tomatoes and in Poniente de Almería they grow up to eight vegetable species, including tomatoes, peppers and cucumber, which cover the greatest surface area.

Once the areas have been chosen, in the initial stage it is considered essential to have basic knowledge of the current state of technology and equipment in the greenhouses. To do so, used existing documentation and economic and technical literature, and notes taken from the direct inspection of the reference areas of the study and interviews conducted with cooperatives and technicians located in these areas.

Once sufficient information had been obtained, the survey on which the work is based, was drawn up and carried out, with the corresponding questionnaire, the wording of which established the main topic of analysis to be current state of technology, aimed at disclosing its ongoing development. The issues concerning greenhouse technology give priority to highest level on each farm. Special attention was paid to soilless culture, as it is the most advanced form of cultivation today.

Greenhouse components

This description contributes to gathering information about the state of the art and composition of the greenhouses, and it is essential to take this into account in the survey questionnaire.

Structure

In particular one should note the crucial role of the structure in terms of size, which defines the type of installation and allows, to a greater or lesser extent, the placement of components that enhance and complement the climate control functions in the greenhouse, thereby exerting a favorable effect on product amount and quality.

Parral type greenhouses, with a cheaper structure, have numerous drawbacks, such as poor temperature control due to low height. Also the slightly sloping roof and covering cause loss of light. It is not possible to incorporate components whose placement depends on the structure and the only improvements possible are in the zenithal and lateral motorized ventilation.

When the greenhouse is the improved parral type, as well as enhancing the microclimate inside, it is more feasible to incorporate screens of various kinds and other climate control devices like destratifiers and misting systems.

Multi-tunnel structures can house equipment suitable to establish climatic conditions that increase product quantity and quality. They are also prepared for the demands of soilless culture and can fully support complementary equipment that may include: fans, heat shields and shading, destratifiers, misting systems, permanent heating systems, and implementation of CO_2 and recycling solutions.

Climate control devices

In recent years they have built greenhouses covered with mesh, which require lower investment. The mesh acts as a windbreak and shading, and also prevents or restricts the access of insects. The effect on production schedule is slight.

Insect-proof mesh placed in windows and covering the entrance to fans, have widespread use in the three study areas and are essential for biological control.

There are ventilation and cooling solutions to curb excessively high temperatures. The most commonly used ventilation systems are the passive kind, through lateral and zenith windows, which can have an elementary structure with manual operation, or mechanized opening and closing, including programming.

Insulation systems are also action in the passive climate control systems, which include screens and double inflatable covering. Shading screens to reduce heat. Although more expensive compared to the practice of applying whitewash, they have the advantage of providing more homogeneous effect and greater flexibility and automation (Callejón *et al*., 2003). The double inflatable covering is very effective in reducing heat losses, but has the disadvantage of reducing light transmission. The following are considered as active temperature reducing devices. Forced ventilation, to bring in or to extract air, for which fans are needed. Cooling by evaporating water can be done by misting with high or low pressure. Finally, to correct stratification of the air inside the greenhouse and achieve greater consistency of the temperature, destratification fans are used.

Heating

Although in temperate regions plastic greenhouses provided the most suitable environment for intensive horticulture; it was not long before the use of heat generators was found to avoid the risk of frost, occurring a few days per year.

In a few years, greenhouses were developed and perfected, and thanks to international experience, especially in Europe, knowledge had been accumulated for each species concerning the effects of temperature on growth, according to the phenological stages of the plant. In a study of pepper cultivation in greenhouses, the use of heating increased the earliness, total and marketable production while the proportion of unmarketable produce dropped (Fernández-Zamudio *et al*., 2006).

There are two types of heating, hot air and hot water. Hot air heating is used to avoid momentary drops in temperature. Hot water heating is used for systems on a more permanent basis, and the most commonly used is piped water at 30-40°C through polypropylene corrugated pipes, compared to those which have higher installation costs, carrying water at 80-90ºC through steel or aluminum pipes.

Irrigation and fertirrigation

The most commonly used irrigation systems in greenhouses are high frequency drip irrigation systems. The fertirrigation that is applied with this system, supplies the plant with all the nutrients they need via the irrigation water. This requires the installation of a fertilizer tanks at the irrigation tube header upstream, in which the fertilizer solution is poured and then passes through the irrigation network via Venturi type suction systems or batcher pumps. Irrigation systems have reached high levels of programming and automation.

Soilless culture

Soilless culture in horticulture is a highly significant innovation given what it represents in terms of technology and investment in equipment. In general, it requires a high greenhouse structure, able to support climate conditioning devices with automatic opening and closing windows, and zenithal ventilation, fully equipped and programmable irrigation and fertirrigation systems. Also the provision of permanent heating is advisable, although depending on the growing area and crop, soilless culture is also frequent in greenhouses without heating or with temporary heating.

Recirculation of nutrient solutions

Installation of this system is linked to soilless culture. It is worth noting that this technique is highly advanced but not fully developed and it is an application whose interest lies more in the fact it is environmentally friendly than economic; in most cases, its viability is partial and its adoption seems to be limited.

CO_2 fertilization

Carbon fertilization techniques have been carried out in central and northern Europe for years, and have been adapted to certain situations in Spain, considering the environmental conditions of our country. It can be considered a well-developed technique, although its application is associated with intensive crop cultivation with high yields and incomes. In order to apply this mode, greenhouses must be of high-quality construction, for which reason it has been used in soilless culture.

In order to distribute the CO_2, distribution pipes can be placed within the crop so that the enriched air passes through the vegetation before rising up (Castilla, 2005).

Computerization and horticulture

Currently, some horticultural growers have equipped their greenhouses and facilities with equipment that makes climate control possible, which has been facilitated by technological progress and the fact it has become cheaper (Martínez *et al*., 2002).

Through mathematical models that enable automatic decision-making, it is possible to integrate climate control with adjustment of the water and fertilizer supply to the plants. In addition, through the previously programmed information, the system can detect any changes that occur in growing conditions and set off warning alarms (Alarcón, 2003).

Mechanization of cultivation tasks

This is a very important concept given the effect on efficient use of the labor and the competitiveness of production processes. It covers all cultivation tasks, especially plant protection product application, operation like clipping, pruning and training, and harvesting. When plant protection product application is not done from outside the greenhouse, it must be done by trying to avoid operator contact with the products inside the greenhouse, and to do so, machinery is used to apply products at a distance or via fixed installations. With respect to collection and other cultivation tasks, the most suitable systems are lift platforms on rails.

Methodology and its application

The development work, based on empirical analysis of data gathered through a survey, requires the choice and description of the methodology to be used to deal with the information obtained. It includes the following sections: sampling, application of cluster analysis to determine levels of technology and bivariate statistical analysis with a test for independence.

Sample size and representativeness

Random sampling was stratified proportional, to the number of owners with greenhouses, in the areas of El Ejido (Almería), Valle del Guadalentín and Campo de Cartagena (Murcia) and South of Alicante. The population size comprising 6,917 greenhouse owners, with the strata corresponding to El Ejido (Almería) with 3,714 owners, Campo de Cartagena (belonging to Southern Alicante and Murcia) and Valle del Guadalentín (Murcia) with 1,888 and 1,314 owners, respectively. The sample size, calculated by proportions, is:

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

where n = simple size, N = population size, k = coefficient depending on the confidence level of the results, p = percentage of the population having the characteristic, q = percentage of the population without the characteristic (1-p), and e = maximum permissible error for a confidence level of 95%.

The sample size for a confidence level of 95% and a maximum permissible error of ± 6%, is 257 surveys, some of which had to be rejected because a large number of questions were unanswered, leaving a final total of 242 surveys, for which the sampling error is ± 6.2%.

It should be noted that the maximum permissible error of ± 6.2% is the case that the estimate of the proportion is 50%, *i.e.,* $p = q = 0.5$ this being the worst situation. However, for $p = 0.4$ (or $p = 0.6$) the sampling error will be ± 6.1%; for $p = 0.3$ (or $p = 0.7$) would be ± 5.7% and if $p = 0.2$ (or $p = 0.8$) it would be ± 5%.

The number of surveys are distributed by strata as follows: El Ejido represents 53.7% of the sample, with 130 surveys; Valle del Guadalentín represents 19.0%

of the total and Campo de Cartagena 27.3%, both total 112 surveys.

The data collection method was via personal and individual interview of the greenhouse owners, on the number indicated by the sample size, chosen at random from the list of owners. These interviews were conducted by interviewers who are specialized technicians in the production carried out in these areas (Table 1).

Once this phase of the fieldwork was complete, in the first half of 2007, and the interview questionnaires had been reviewed to check their validity and possible error correction, we went on to code the responses, which yielded qualitative and quantitative variables.

Determining levels of technology through cluster analysis

Installing technology in greenhouses, increasing the number of components or introducing changes in farming techniques can be done from the start with proper planning, or applied to an existing facility which can be extended by successively adding components. The addition of components may be very haphazard, and resulting from owners' decisions about investments, which are highly variable, without achieving a uniform growth or improvement. Therefore, to study the technological development, grouping into different levels seems more appropriate, which can be done following strictly technical criteria designed by highly specialized professionals in the field, based on grouping together components related to each other and which fulfill the requirements of the crop more or less perfectly.

The monographic work by Hernández *et al*. (2000), on greenhouse equipment and technology, points out the need for improvement of the models in order to optimize investment. In the aforementioned work, in principle, greenhouses are grouped according to their structural characteristics as either parral or multi-tunnel. Technological packages are assigned to these types, giving rise to four levels in parral-type and five in the multitunnel-type.

Table 1. Technical data of the survey

Population	Owners of farms with greenhouses
Location	Valle del Guadalentín, Campo de Cartagena and El Ejido (Almería)
Survey type	Personal interview
Population size	6,917 owners of farms within the scope of the survey
Sample size	242 questionnaires
Sampling error	± 6.2%
Confidence level	95% (K = 1.96)
Sampling type	Stratified random sampling
Field-work date	June 2006 to January 2007
Prior questionnaire	Pilot test with 10 farmers

The article by Fernández-Zamudio *et al.* (2006) analyses the characteristics of the technology, and their possible developments, in greenhouses growing peppers located in the Campo de Cartagena. To do so, greenhouses are grouped according to technical allocation, growing techniques and quality that could be obtained, at four technological levels, two with cultivation on soil and two with soilless culture. The grouping of components that characterize each level basically adheres to the characteristics and dimensions of the structure, presence or not of heating and whether this is by air or water, of temporary or permanent use. Irrigation installations with fertirrigation and the level of automation are also important and, finally, the higher level considers the use of carbon fertilization and nutrient solution recycling. The publication concludes with an economic assessment of the results of pepper growing at each of the levels analyzed.

The technical criteria, despite being followed with a high degree of rationality, may be highly variable and to some extent of a subjective nature. Therefore, this paper proposes an analysis based on a multivariate technique, cluster analysis, which leads to a classification by groups comprised of homogeneous individuals and so that there is heterogeneity between groups (Peña, 2002). In this case, pre-determined technology package is not adopted; rather it is the mathematical algorithm that forms the groups by removing subjectivity. However, given the importance of technology in soilless culture, which is of considerable emphasis in this study, prior to applying the cluster analysis, information from the questionnaires was separated according to whether it referred to soil-based to soilless culture.

Cluster analysis methodology

This is a multivariate statistical method of interdependence given that all the variables play the same role, without one or more being dependent on others. Cluster analysis is useful to classify individuals into categories and can also be used to classify variables. In this case, it is used to group farms according to their level of greenhouse technology and enables homogeneous groups to be formed according to observed variables.

Cluster analysis has frequently been used in marketing for many purposes, such as market segmentation and analysis of consumer behavior (Pulido *et al*., 2001), among others. It has also been applied to agricultural research, especially in developing farm typologies, which includes a study by Pardos *et al.* (2008) which typifies a group of mutton producing farms, using sociological, structural, technical and economic variables. In the study «Characterization of broiler farms in the Comunitat Valenciana» (Martínez *et al*., 2008), as well as performing a comprehensive descriptive analysis, broiler coops are divided into three major groups and, using this typology, they identify the variables responsible for differentiating coops into these three groups.

The hierarchical clustering procedure was followed, starting off with as many groups as there were individuals, and in the following steps the closest individuals were joined into new clusters, reducing in number with each step of the analysis. Ultimately, all individuals are grouped into one cluster, giving rise to a structure shaped like an inverted tree, called a dendrogram, where the results of the first steps are nested inside the subsequent ones.

The cluster method applied to calculate the distances between clusters was the Ward Method for binary data, using the number of discordant cases as a measure of proximity.

Considering soilless culture as the central axis around which the different technological components are installed, on applying the methodology, individuals with cultivation in soil and soilless cultivation were previously separated.

We have gone on to analyze individuals with soil cultivation, on one hand, yielding three distinct groups, and on the other hand, individuals with soilless cultivation, which has given two groups. The software used was SPSS 13.0 for Windows.

The 24 input variables in the analysis are dichotomous variables (1 = presence of characteristic; 0 = absence of the characteristic) and are listed in Table 2, together with their description.

Table 3 shows the correlations between binary variables, so the Phi coefficient between each pair of variables with *p*-value.

Bivariate analysis: test for independence

The statistic χ^2 of Pearson has been used, defined as follows:

$$\chi^2 = \sum_{i=1}^{k} \sum_{j=1}^{r} \frac{\left(n_{ij} - \frac{n_i \cdot n_j}{n} \right)^2}{\frac{n_i \cdot n_j}{n}}$$

where n_{ij} is the observed frequency in the cell of row i and column j; $\frac{n_i \cdot n_j}{n}$ is the expected frequency (in the cell of row i and column j) in the case where variables are independent; k is the number of rows and r is the number of columns in the contingency table in order $k \times r$.

The statistic quoted allows the hypothesis of independence in the contingency table based on the chi square with $(k-1) \times (r-1)$ degrees of freedom. Such that if $\chi^2 \leq \chi^2_{(k-1)\cdot(r-1)}(\alpha)$ is true, then we cannot reject H_0. The significance level used for the test is indicated by α.

In the event of rejecting the null hypothesis of independence between variables, one can say that with a confidence level (1-α) there is a relationship among the variables studied. The statistical program used was Statgraphics Plus 5.1.

Results

The cluster analysis is used to classify the greenhouses at different levels of technology via the formation of groups. Table 4 presents the results of the two cluster analyses together, showing the proportions of each variable in each of the five groups obtained: the first three, with cultivation in soil, and the other two, with soilless culture.

Composition and characteristics of the technological levels

At first sight, the results in Table 4 would seem to indicate classifying the greenhouses surveyed into five groups is both sufficient and suitable. Among the advantages in using the cluster technique we can see, on the one hand, the number of individuals assigned to each group and in turn, those within each and the proportion of individuals who have a particular variable or item.

According to the methodology applied, once the groups have been formed by all the items they encompass, the technical characteristics of the different combinations are derived and the impact they have on

Table 2. Description and identification of the variables analyzed

Variables	Identification	Description
Air heating	AiH	1 = if air heating is installed; 0 = otherwise
CO_2 fertilization	CO_2	1 = if CO_2 fertilization is installed; 0 = otherwise
Computerized irrigation & fertirrigation	CIF	1 = if computerized irrigation & fertirrigation is installed; 0 = otherwise
Exterior shading meshes	ESM	1 = if exterior shading meshes are installed; 0 = otherwise
Fans	Fan	1 = if fans are installed; 0=otherwise
Flexible plastic full covering	FlP	1 = if is flexible plastic full covering; 0 = otherwise
High-temperature heating	HtH	1 = if high-temperature heating is installed; 0 = otherwise
Insect-proof mesh	IM	1 = if insect-proof mesh is installed; 0 = otherwise
Interior shading meshes	ISM	1 = if interior shading meshes are installed; 0 = otherwise
Irrigation pool	IrP	1 = if it has irrigation pool; 0 = otherwise
Lift platforms	LiP	1 = if lift platforms are installed; 0 = otherwise
Manually opened windows	MOW	1 = if manually opened windows are installed; 0 = otherwise
Misting	Mis	1 = if misting is installed; 0=otherwise
PVC fronting	PVC	1 = if it has PVC fronting; 0 = otherwise
Permanent heating	PeH	1 = if permanent heating is installed; 0 = otherwise
Programmed climate control	PCC	1 = if programmed climate control is installed; 0 = otherwise
Programmed irrigation & fertirrigation	PIF	1 = if programmed irrigation & fertirrigations is installed; 0 = otherwise
Rails	Rai	1 = if rails are installed; 0 = otherwise
Simple irrigation programming	SIP	1 = if simple irrigation programming is installed; 0 = otherwise
Structural material of the greenhouse	Str	1 = if is steel structure; 0 = otherwise
Temporary heating	TeH	1 = if temporary heating is installed; 0 = otherwise
Thermal screens	ThS	1 = if thermal screens are installed; 0 = otherwise
Type of greenhouse structure	Typ	1 = Parral; 0 = Multitunnel
Water heating	WaH	1 = if water heating is installed; 0 = otherwise.

the improvement represented by transition from one level to a higher one.

Below is a description of the five technological levels based on the items it comprises and their utility function.

Level 1

This is the most rudimentary and least developed, formed by parral type greenhouses covered with flexible plastic, mostly; only 9% of greenhouses in this group are covered with mesh. In those with plastic covering, window opening is manual and there is no heating.

The proportion of greenhouse with an irrigation pool is also high in this group, therefore this item does not differentiate groups. The fact they are present in high proportions stems from the need to supply permanent irrigation and fertirrigation demands, as well as water storage needed, which is common in these very dry areas where the greenhouses are located.

Although farmers often prioritize their investments to improve irrigation systems, less than half the greenhouses in this group have even a simple irrigation programming device and the proportion of computerized irrigation and fertirrigation systems reach only 10.8%. A very positive aspect, despite the simple composition of the greenhouses in this group, is that most have insect-proof meshes (84.9%), making it feasible to move towards integrated production using biological control.

Level 2

Steel structures predominate in this level, although some (11.5%) are made of wood. The covering is flexible plastic and a few greenhouses are covered with mesh. In this group the parral type is the most common, most

Table 3. Phi correlation coefficients (φ) for the variables

		Str	PVC	FIP	IrP	SIP	PIF	CIF	Typ	Rai	LiP	CO_2	InM	ThS	ISM	ESM	Mis	Fan	AiH	WaH	TeH	PeH	HtH	MOW	PCC
Str	φ	1.000	0.042	−0.072	−0.390	−0.224	0.049	0.119	−0.100	0.018	−0.028	0.018	0.008	0.870	0.075	0.070	0.073	0.008	−0.002	0.081	0.059	0.032	0.052	−0.117	0.087
	P-valor		0.517	0.262	0.549	0.000	0.446	0.650	0.118	0.776	0.669	0.776	0.906	0.174	0.241	0.275	0.257	0.906	0.975	0.210	0.359	0.621	0.415	0.069	0.174
PVC	φ		1.000	−0.808	0.014	−0.056	−0.093	0.327	−0.717	0.194	0.008	0.194	−0.086	0.339	0.134	0.036	0.086	0.355	0.043	0.327	0.003	0.300	0.170	−0.531	0.438
	P-valor			0.000	0.832	0.387	0.149	0.000	0.000	0.003	0.906	0.003	0.180	0.000	0.038	0.577	0.180	0.000	0.506	0.000	0.964	0.000	0.008	0.000	0.000
FIP	φ			1.000	−0.014	0.110	0.155	−0.257	0.563	−0.157	0.019	−0.157	0.576	−0.248	−0.079	0.002	−0.040	−0.255	−0.005	−0.241	0.025	−0.211	−0.121	0.398	−0.322
	P-valor				0.832	0.087	0.016	0.000	0.000	0.015	0.767	0.015	0.000	0.000	0.218	0.979	0.534	0.000	0.933	0.000	0.700	0.010	0.061	0.000	0.000
IrP	φ				1.000	−0.166	0.251	−0.102	−0.026	0.021	0.064	0.021	−0.025	0.000	−0.027	−0.100	0.025	−0.014	0.015	−0.015	−0.003	0.001	−0.019	−0.049	0.100
	P-valor					0.010	0.000	0.1415	0.688	0.745	0.321	0.745	0.695	0.997	0.677	0.119	0.695	0.823	0.812	0.819	0.964	0.992	0.772	0.444	0.119
SIP	φ					1.000	−0.461	−0.203	0.05	−0.031	0.072	−0.031	0.037	−0.037	−0.087	−0.075	−0.037	−0.049	−0.116	−0.058	−0.101	−0.075	−0.031	0.050	0.000
	P-valor						0.000	0.002	0.103	0.627	0.264	0.627	0.563	0.564	0.178	0.244	0.563	0.445	0.072	0.371	0.117	0.243	0.633	0.434	0.996
PIF	φ						1.000	−0.398	0.101	−0.061	−0.012	−0.061	0.142	−0.117	0.146	0.048	0.099	−0.045	0.142	−0.143	0.093	−0.060	−0.176	0.158	−0.205
	P-valor							0.000	0.117	0.340	0.851	0.340	0.028	0.069	0.023	0.458	0.125	0.480	0.028	0.027	0.150	0.355	0.006	0.014	0.001
CIF	φ							1.000	−0.368	0.154	0.041	0.154	0.011	0.366	−0.018	0.095	0.037	0.311	0.003	0.412	0.091	0.290	0.377	−0.455	0.449
	P-valor								0.000	0.017	0.528	0.017	0.862	0.000	0.782	0.138	0.565	0.000	0.963	0.000	0.156	0.000	0.000	0.000	0.000
Typ	φ								1.000	−0.182	−0.069	−0.182	0.018	−0.543	−0.064	−0.025	−0.072	−0.354	−0.032	−0.450	0.008	−0.450	−0.375	0.675	−0.543
	P-valor									0.005	0.283	0.005	0.782	0.000	0.318	0.702	0.261	0.000	0.623	0.000	0.902	0.000	0.000	0.000	0.000
Rai	φ									1.000	0.328	−0.004	0.017	−0.020	0.242	−0.016	−0.017	0.175	−0.015	−0.018	−0.013	−0.020	−0.012	−0.157	0.209
	P-valor										0.000	0.949	0.797	0.757	0.000	0.804	0.797	0.007	0.811	0.776	0.835	0.757	0.853	0.015	0.001
LiP	φ										1.000	−0.013	0.051	0.017	0.036	−0.049	0.040	0.129	0.050	0.027	0.069	0.017	0.086	−0.043	0.095
	P-valor											0.844	0.432	0.792	0.582	0.449	0.533	0.044	0.439	0.672	0.286	0.795	0.182	0.504	0.141
CO_2	φ											1.000	0.017	0.029	−0.017	−0.016	0.251	0.175	−0.015	0.227	−0.013	0.209	0.38	−0.157	0.209
	P-valor												0.797	0.001	0.790	0.804	0.000	0.007	0.811	0.000	0.835	0.001	0.000	0.015	0.001
InM	φ												1.000	0.018	0.068	0.064	0.066	0.095	0.062	0.008	0.054	0.019	−0.048	−0.009	0.018
	P-valor													0.75	0.287	0.322	0.304	0.140	0.340	0.903	0.405	0.772	0.452	0.893	0.775
ThS	φ													1.000	−0.023	−0.076	0.043	0.383	−0.009	0.864	0.009	0.791	0.600	−0.708	0.426
	P-valor														0.721	0.235	0.508	0.000	0.893	0.000	0.883	0.000	0.000	0.000	0.000
ISM	φ														1.000	0.005	0.001	0.055	0.010	−0.012	−0.055	0.036	−0.049	0.015	0.036
	P-valor															0.934	0.993	0.388	0.875	0.848	0.389	0.578	0.444	0.812	0.574
ESM	φ															1.000	−0.064	0.072	0.176	−0.071	0.215	−0.077	−0.046	0.052	−0.014
	P-valor																0.322	0.262	0.006	0.273	0.001	0.234	0.476	0.419	0.834
Mis	φ																1.000	0.169	0.091	0.057	0.119	0.042	0.048	−0.089	0.164
	P-valor																	0.009	0.160	0.372	0.066	0.512	0.452	0.168	0.011
Fan	φ																	1.000	0.19397	0.380	0.115	0.428	0.288	−0.354	0.338
	P-valor																		0.003	0.000	0.074	0.000	0.000	0.000	0.000
AiH	φ																		1.000	−0.068	0.779	0.194	−0.044	0.044	−0.074
	P-valor																			0.292	0.000	0.003	0.492	0.491	0.252
WaH	φ																			1.000	0.024	0.857	0.652	−0.656	0.416
	P-valor																				0.713	0.000	0.000	0.000	0.000
TeH	φ																				1.000	−0.064	−0.039	0.027	−0.064
	P-valor																					0.318	0.550	0.675	0.318
PeH	φ																					1.000	0.600	−0.624	0.374
	P-valor																						0.000	0.000	0.000
HtH	φ																						1.000	−0.450	0.518
	P-valor																							0.000	0.000
MOW	φ																							1.000	−0.750
	P-valor																								0.000
PCC	φ																								1.000

Table 4. Proportion of the variables at each technological level

Variables	Technologica levels				
	Cultivation in soil			Soilless culture	
	1	2	3	4	5
No. individuals/cluster	93 (39%)	78 (33%)	14 (6%)	39 (16%)	14 (6%)
Air heating	1.1%	6.4%	0.0%	12.8%	14.3%
Water heating	0.0%	0.0%	42.9%	0.0%	78.6%
Temporary heating	1.1%	5.1%	7.1%	7.7%	7.1%
Permanent heating	0.0%	1.3%	35.7%	5.1%	85.7%
High-temperature heating	0.0%	0.0%	7.1%	0.0%	50.0%
Steel structure	90.3%	88.5%	100.0%	97.4%	100.0%
PVC fronting	2.2%	3.8%	71.4%	0.0%	57.1%
Flexible plastic full covering	86.0%	93.6%	28.6%	100.0%	42.9%
Parral-type	98.9%	92.3%	21.4%	100.0%	21.4%
Insect-proof mesh	84.9%	97.4%	92.9%	100.0%	92.9%
Thermal screens	1.1%	1.3%	50.0%	0.0%	85.7%
Exterior shading mesh	1.1%	11.5%	0.0%	10.3%	14.3%
Interior shading mesh	4.3%	9.0%	0.0%	5.1%	7.1%
Misting	1.1%	5.1%	7.1%	15.4%	14.3%
Fans	2.2%	5.1%	28.6%	15.4%	78.6%
Manually opened windows	92.5%	96.2%	0.0%	100.0%	7.1%
Programmed climate control	5.4%	1.3%	42.9%	0.0%	64.3%
CO_2 fertilization	0.0%	0.0%	0.0%	0.0%	7.1%
Simple irrigation programming	45.2%	0.0%	14.3%	5.1%	0.0%
Programmed irrigation & fertirrigation	2.2%	92.3%	35.7%	74.4%	21.4%
Computerized irrigation & fertirrigation	10.8%	0.0%	42.9%	20.5%	78.6%
Irrigation pool	83.9%	94.9%	92.9%	94.9%	85.7%
Rails	0.0%	0.0%	0.0%	0.0%	7.1%
Lift platforms	3.2%	3.8%	0.0%	2.6%	14.3%

of which have undergone improvement, and it also includes some (7.7%) multi-tunnel type greenhouses.

Noteworthy at this level, is the allocation to irrigation systems, almost all the units have a pond and programmed irrigation and fertirrigation systems. There is a significant proportion with meshes, for both external and internal shading. The proportion with temperature control devices is low: 5.1% have misting, while 6.4% have air-heating systems, though it is used only at specific times. The whole group has insect-proof meshes installed. A drawback of the greenhouses in this group concerns the window opening, which is almost entirely manual.

Level 3

It is within this group that there is a major technological leap. There is a predominance of multitunnel type structure, which is steel in all cases; greenhouses are PVC fronted in most cases and the plastic covering is flexible. Unlike the two previous levels, half have computerized irrigation and fertirrigation systems while the other half have a programmer.

With respect to temperature control, the level is considered to be good, as half have thermal screens. Almost one third have fans and 42.9% have water heating installation, used permanently in 36% of cases, which in some reach high temperatures. Window opening is never manual and climate control programming represents 42.9%. All greenhouses in this group have insect-proof meshes.

In summary, it is evident that technological progress in this group is quite acceptable. The proportion of multitunnel greenhouses is similar to that in Level 5, the most advanced, and it seems clear that this group includes owners who have made significant investments in the soil cultivation, but are reluctant to move towards soilless culture.

Level 4

There is notable progress in terms of the adoption of soilless culture; notwithstanding, overall equipage is lower compared to Level 3. The type of greenhouse is improved parral with a steel frame and 100% flexible plastic covered. Irrigation and fertirrigation installations reach acceptable levels, of which 80% are programmed and 20.5% are computerized. It is the group with the highest proportion of misting facilities, even though this represents only 15.4% of cases, which would indicate that this cooling system does not reach adequate proportions. Fans are installed in the same proportion as misting systems. 100% of the greenhouses in this group are equipped with insect-proof mesh.

External shading mesh is found in 10.3% while in 5.1% this is inside. Air-heating systems are is predominant in 12.8% of cases, but only two of these use it on a permanent basis. The owners did not seem inclined to invest in permanent water heating facilities.

Level 5

This is without doubt the most highly developed. In most cases the multitunnel structure type is chosen made of steel with flexible plastic covering and fronted with PVC in over half the cases. There is an outstanding proportion of computerized irrigation and fertirrigation, representing 78.6% of cases.

Regarding climate-control devices, the majority of the greenhouses have screens and fans. To a lesser extent, there are interior and exterior shading meshes and misting systems. Provision of control equipment is completed by insect-proof mesh, which is essential for biological control.

The provision of heating is also characteristic of this group, reaching 93% of greenhouses; 85.7% have permanent heating and 50% reach high temperatures.

Programming of climate control devices is installed in 64.3% of the greenhouses in this group. This is the only group that has rails installed, albeit in a low proportion; however, lift platforms are scarce.

A distinctive feature of this group, compared with the other four, is the presence of CO_2 fertilization installations, at a rate of 7.1%.

This group, although not large, represents an ideal in terms of equipage of Mediterranean horticultural greenhouses, with which it is possible to achieve high levels of climate control and fertirrigation, which is necessary nowadays in order to obtain quality and to grow select varieties.

Relationship between the technological levels in greenhouses and variables of interest

Once the groups had been defined and characterized, it has come to deduce the relationship between each group with certain relevant characteristics of the farm, gleaned from information obtained in the questionnaires. To do so, cross-frequency tables were drawn up, with variables being subjected to a test for independence. Only significant results of significant variables are expressed, which correspond to: areas of study, crop type, age of farmers, owners' willingness to incur debt and subsidies or loans received.

Study areas

The set of farms making up each technological level, is highly related to the three areas where the study took place, since a very high total χ^2 is obtained (Table 5).

It is noteworthy that Campo de Cartagena has the most advanced facilities, which is evident by the percentages corresponding to groups 3 and 5 that are higher than in other areas. Moreover, their contribution is to χ^2 is high and one observes a greater frequency than expected under the independence hypothesis.

Valle del Guadalentín has lower levels of development, probably due to the fact that it specializes in tomato cultivation. The proportion of group 1, the simplest level, is very high, and its contribution to total is high too, to which we should add the positive association between the area and the group, which means that the observed frequency in the Valle de Guadalentín for group 1 is higher than expected under the independence hypothesis.

Finally, the area of El Ejido has the largest percentage of Level 2, which shows that important development has taken place in the past 15 years regarding the more primitive flat greenhouses. Noteworthy is the trend towards an increased proportion of greenhouses in Level 4, which corresponds to soilless culture type but not fully equipped. One can see that, both in Level 2 and 4, the association between group and region is positive, thus one can deduce that in El Ejido the incidence of these greenhouses is often higher than expected under the independence hypothesis.

Table 5. Distribution of the technological levels in the greenhouses according to region

Technological levels	Zone			Row total
	Campo Cartagena	Valle Guadalentín	El Ejido	
Level 1				
Observed frequency	25	32	36	93
Row percentage	26.88%	34.41%	38.71%	39.08%
Observed-expected frequency	–0.01	14.03	–14.02	
Contribution to χ^2	0.00	10.94	3.93	
Level 2				
Observed frequency	10	9	59	78
Row percentage	12.82%	11.54%	75.64%	32.77%
Observed-expected frequency	–10.97	–6.08	17.05	
Contribution to χ^2	5.74	2.45	6.93	
Level 3				
Observed frequency	14	0	0	14
Row percentage	100.00%	0.00%	0.00%	5.88%
Observed-expected frequency	10.24	–2.71	–7.53	
Contribution to χ^2	27.83	2.71	7.53	
Level 4				
Observed frequency	2	5	32	39
Row percentage	5.13%	12.82%	82.05%	16.39%
Observed-expected frequency	–8.49	–2.54	11.03	
Contribution to χ^2	6.87	0.85	5.80	
Level 5				
Observed frequency	13	0	1	14
Row percentage	92.86%	0.00%	7.14%	5.88%
Observed-expected frequency	9.24	–2.71	–6.53	
Contribution to χ^2	22.66	2.71	5.66	
Column	64	46	128	238
Total	26.89%	19.33%	53.78%	100.00%

$\chi^2 = 112.60$. Degrees of freedom = 8. *P*-value = 0.000.

Crop type

On analyzing the technological levels according to crop type, the total obtained has a highly significant p-value, which indicates there is dependence between the crop type and the technological level to which they are most often assigned (Table 6).

The pepper is more uniformly distributed with higher proportions of the three higher levels compared with other crops, which can be explained by the fact this crop is more demanding and it responds better to investment made in equipment. The results show how in Level 1, the simplest, the observed frequency is lower than expected under the independence hypothesis. The contrary can be seen in Levels 3 and 5, where a positive association, *i.e.* the observed frequency, is higher than expected, to which we must add a strong contribution to χ^2.

The tomato is one of the least demanding horticultural species growing under shelter. A large proportion of greenhouses are assigned to Level 1, with this cell making the greatest contribution to χ^2 and a positive association. The modality chosen when the tomato crop is grown under more demanding conditions, is soilless culture without permanent heating, *i.e.* Level 4.

Cucumber and other crops behave similarly to tomatoes, although the highest percentage corresponds to Level 4 and there is also an important proportion of Level 2. In these cases the contributions to total χ^2 are lower.

Table 6. Distribution of the technological levels in the greenhouses according to crop specialization

Technological levels	Crop type				Row total
	Pepper	Tomato	Cucumber	Others	
Level 1					
Observed frequency	38	32	18	5	93
Row percentage	40.86%	34.41%	19.35%	5.38%	39.08%
Observed-expected frequency	–10.06	11.68	–0.76	–0.86	
Contribution to χ^2	2.11	6.71	0.03	0.13	
Level 2					
Observed frequency	42	12	18	6	78
Row percentage	53.85%	15.38%	23.08%	7.69%	32.77%
Observed-expected frequency	1.69	–5.04	2.27	1.08	
Contribution to χ^2	0.07	1.49	0.33	0.24	
Level 3					
Observed frequency	14	0	0	0	14
Row percentage	100.00%	0.00%	0.00%	0.00%	5.88%
Observed-expected frequency	6.76	–3.06	–2.82	–0.88	
Contribution to χ^2	6.32	3.06	2.82	0.88	
Level 4					
Observed frequency	16	8	11	4	39
Row percentage	41.03%	20.51%	28.21%	10.26%	16.39%
Observed-expected frequency	–4.16	–0.52	3.13	1.54	
Contribution to χ^2	0.86	0.03	1.25	0.97	
Level 5					
Observed frequency	13	0	1	0	14
Row percentage	92.86%	0.00%	7.14%	0.00%	5.88%
Observed-expected frequency	5.76	–3.06	–1.82	–0.88	
Contributionto χ^2	4.59	3.06	1.18	0.88	
Column	123	52	48	15	238
Total	51.68%	21.85%	20.17%	6.30%	100.00%

χ^2 = 37.01. Degrees of freedom = 12. *P*-value = 0.0002.

Age of farmer

Although the farmer's age and the technological level of their greenhouse were expected to be related, according to the results obtained there is no evidence that there is dependency between these two variables, since χ^2 has a value of 11.40 with 8 degrees of freedom (*P*-value = 0.1801).

Readiness to assume debt

On analyzing the technological levels of the greenhouses according to readiness to assume debt, a considerably higher χ^2 is obtained, indicating that there is dependency between willingness to borrow money and the technological level of greenhouses (Table 7).

When willingness to take on business loans is very low, this most frequently insides with Level 3, however, this can be considered a logical result, both in the relative frequencies and the number of greenhouses in this column corresponding to Levels 1 and 2. When it is low, although the highest percentage of the row corresponds to Level 4, with the highest total contribution to the chi-square in the table and a positive association, the largest number of units is accumulated in Levels 1 and 2.

Farmers who are indifferent to this issue are distributed slightly more evenly, this being the group that is most willing to choose the highest level of technology with 42.86% in the percentage row.

Table 7. Distribution of the technological levels in the greenhouses according to owners' readiness to assume debt

Technological levels	Readiness to assume debt					Row total
	Very low	Low	Indifferent	High	Very high	
Level 1						
Observed frequency	37	24	14	8	10	93
Row percentage	39.78%	25.81%	15.05%	8.60%	10.75%	39.08%
Observed-expected frequency	6.52	–2.57	–7.88	1.75	2.18	
Contribution to χ^2	1.40	0.25	2.84	0.49	0.61	
Level 2						
Observed frequency	20	25	22	4	7	78
Row percentage	25.64%	32.05%	28.21%	5.13%	8.97%	32.77%
Observed-expected frequency	–5.56	2.71	3.65	–1.24	0.45	
Contribution to χ^2	1.21	0.33	0.72	0.29	0.03	
Level 3						
Observed frequency	6	0	6	2	0	14
Row percentage	42.86%	0.00%	42.86%	14.29%	0.00%	5.88%
Observed-expected frequency	1.41	–4.00	2.71	1.06	–1.18	
Contribution to χ^2	0.43	4.00	2.22	1.19	1.18	
Level 4						
Observed frequency	10	18	8	1	2	39
Row percentage	25.64%	46.15%	20.51%	2.56%	5.13%	16.39%
Observed-expected frequency	–2.78	6.86	–1.18	–1.62	–1.28	
Contribution to χ^2	0.61	4.22	0.15	1.00	0.5	
Level 5						
Observed frequency	5	1	6	1	1	14
Row percentage	35.71%	7.14%	42.86%	7.14%	7.14%	5.88%
Observed-expected frequency	0.41	–3.00	2.71	0.06	–0.18	
Contribution to χ^2	0.04	2.25	2.22	0.00	0.03	
Column	78	68	56	16	20	238
Total	32.77%	28.57%	23.53%	6.72%	8.40%	100.00%

$\chi^2 = 28.22$. Degrees of freedom = 16. P-value = 0.0298.

Farmers willing to assume debt are also distributed in a relatively even way, with 9.7% in soilless culture, and the highest percentage (14.3%) corresponding to Level 3, because they decide to increase equipment in cultivation in soil rather than taking the leap to soilless culture.

Strong willingness to invest does not coincide with greater dedication to soilless culture and it is somewhat contradictory that only 5.13% and 7.14% of such businesses are located respectively at Levels 4 and 5.

Official subsidies or loans

On analyzing the technological levels of the greenhouses in relation to whether or not they have received subsidies or loans, a high total χ^2 is obtained, implying that there is a relationship between the technological level of the greenhouse and the fact of having received a loan or subsidy (Table 8).

In both situations, the distribution percentages are similar in the first two levels, whereas in the last three, the differences are obvious: without subsidy Level 4 is chosen, while those with subsidy are distributed at the levels with that are equipped with more components, *i.e.* Levels 3 and 5.

Discussion

The formation of groups with levels of technology, deduced from the analysis, has the advantage of distinguishing characteristics of each, the components they

Table 8. Distribution of the technological levels in the greenhouses according to Government subsidies and loans to owners

Technological levels	Government subsidies and loans to owners		Row total
	No	Yes	
Level 1			
Observed frequency	69	24	93
Row percentage	74.19%	25.81%	39.08%
Observed-expected frequency	–1.34	1.34	
Contribution to χ^2	0.03	0.08	
Level 2			
Observed frequency	58	20	78
Row percentage	74.36%	25.64%	32.77%
Observed-expected frequency	–0.99	0.99	
Contribution to χ^2	0.02	0.05	
Level 3			
Observed frequency	8	6	14
Row percentage	57.14%	42.86%	5.88%
Observed-expected frequency	–2.59	2.59	
Contribution to χ^2	0.63	1.96	
Level 4			
Observed frequency	37	2	39
Row percentage	94.87%	5.13%	16.39%
Observed-expected frequency	7.50	–7.50	
Contribution to χ^2	1.91	5.93	
Level 5			
Observed frequency	8	6	14
Row percentage	57.14%	42.86%	5.88%
Observed-expected frequency	–2.59	2.59	
Contribution to χ^2	0.63	1.96	
Column	180	58	238
Total	75.63%	24.37%	100.00%

$\chi^2 = 13.20$. Degrees of freedom = 4. *P*-value = 0.0103.

integrate with the distribution percentages and, also, an indication of how the levels of technology are developing, and to which components farmers give greater priority in the installations and are thus being added, moving from one level to the one above.

On forming groups, one finds that with respect to its components there are not watertight compartments, but rather there are components in varying proportions at more than one level or at all levels. This feature is more in line with reality than if groups were to be formed following expert criteria, basically considering the size of the structure and whether or not they are equipped with components (Fernández-Zamudio *et al*., 2006) or according to a specific greenhouse type (parral or multitunnel) and the allocation of a specific technological package (Hernández *et al*., 2000).

With the established levels, technology is in increasing order in both cultivation modes (soil/soilless). Normally, the groups with soilless culture should have greater technological provision, but this assumption is only fulfilled in Level 5; in Level 3 the majority of components and facilities are better equipped than in Level 4. It seems evident that Level 3 includes farmers who aspire to having good facilities, but without adopting soilless culture.

Concerning farmers' behavior in terms of choosing technology in relation to assuming a debt, there is a willingness to invest in the lowest levels of technology for which provision is low; however, when provision is high or very high they were not inclined to invest in Levels 4 and 5, corresponding to soilless culture.

Insect-proof meshes are not indicative of differences between the levels, given they are installed in all the greenhouses. The growing operations with the greatest impact on the efficiency of labor, have a rather low level of mechanization in all groups.

At all five levels, adoption of technology in irrigation system components were found to be significant and altogether is one of the best equipped areas.

The proportion of heated greenhouses is relatively low and only reaches high rates in Levels 3 and 5. Water heating predominates, where is a higher proportion of permanent heating; meanwhile air-heating systems are often used a specific moments and for back up. In this respect one should note the article by Fernández-Zamudio *et al*. (2006), which concluded that investment in air-heating systems as specific back-up functions, is shown to be a cost-effective option.

An overview of the components facilitating climate control (shading meshes, screens, misting and destratifiers) are found in small proportions. This leads us to believe that greenhouse owners as a whole have not found a clear and effective justification for making economic investment in such installations, which must relate to the potential impact on product quality and harvesting calendar. However, under present conditions, there is a clear need to increase quality by improving climate control in the greenhouses, which implies an increase in their level of technology (Castilla, 2005).

The proportion of farms with greenhouses having the highest levels of technology drops to 6% of the total sample if we consider the allocation of components for soilless culture. Meanwhile for soil cultivation, the greenhouses with acceptable levels of equipage correspond to Level 3. Multitunnel structures, suitable for all kinds of improvements and equipment, only reach a proportion of 11.2%. The lowest levels of technology are found in the most numerous groups, which confirms the slow rate of change.

Technological innovation in greenhouses is essential to strengthen the competitive position of Spanish horticulture (García-Martínez *et al.*, 2009), which is essential in view of foreseeable changes in the markets due to the Euro-Mediterranean Agreement (García-Azcárate and Mastrostefano, 2006) and the effects of globalization.

The picture of the current state of technology in the systems analyzed, and especially in terms of their development, is more comprehensive after the analysis reported here, and could be taken as reference for future studies.

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