DECISION-MAKING IN THE CONTROL OF GREENHOUSE PESTS: A PORTUGUESE CASE STUDY.

by

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Thesis submitted for the degree of Doctor of Philosophy of the University of London and for the Diploma of Imperial College of Science, Technology and Medicine

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December, 1989

Aos
que me ensinaram até onde sabiam,
Mestres
das várias etapas do caminho.

(To
those who taught me what they knew,
Masters
of the several steps of the way.)

ABSTRACT

Greenhouse production systems have distinct characteristics with implications for controlling pest problems. These characteristics are described, along with a brief description of the overall production system in Portugal. A major factor affecting pest problems in this system is the tremendous increase in the production of vegetables in greenhouses in Portugal in recent years.

A survey was done in the two most important greenhouse areas of the country (Algarve and West) to identify the pest problems affecting the Portuguese greenhouse industry. In addition, the survey investigated the decision-making processes adopted by Portuguese growers regarding control methods. The survey included 61 growers, using an interview questionnaire specifically developed for the project.

The survey data was used to describe: a) how growers perceive pest problems on the major greenhouse crops; b) what are the most important pest problems faced; c) how growers choose control methods from the options available; d) how they assess the results achieved from such control methods; e) what are the major difficulties with improving pest control practices; and, f) how growers foresee pest problems in the future and what they believe could improve pest control methods in the future.

Based on such data a descriptive model was used to discuss the decision-making process adopted by Portuguese growers to choose pest control practices. An "Expert-System" shell was used to develop a prototype descriptive model of the actual decision process used for two major pest problems on the main vegetable crop. This may be used in the future as the basis for a tool to disseminate technical information to cooperatives and other groups of growers.

Finally, recommendations are made concerning research and technical needs in order to reduce information gaps identified during this work.

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1 — INTRODUCTION

Greenhouse production systems are unique agroecosystems due to their production features, economic characteristics and aspects related to pests occurring on the crops and their control.

The adoption of plastics in agriculture, slowly during the 1950's and rapidly since the 1960's, allowed the expansion of greenhouses into new areas, the Mediterranean region and Japan being the most impressive examples. The environmental control achieved with plastic structures is in some cases minimal compared with the results obtained with glasshouse structures. However, natural conditions prevailing in the areas with plastic greenhouses are more advantageous for the crops produced and the environmental improvements obtained with plastic structures are sufficient to justify their use.

This expansion in area, which continues to increase steadily in many countries, and the crop intensity associated with greenhouse production, represented either by multiple cropping or intensive monoculture, increases the potential for pest attacks at regional and local levels, resulting in an increased need for control actions from the growers' point of view.

The use of very intensive calendar spraying schemes can present serious drawbacks caused by pest resistance

problems, high costs in terms of labour requirements and pesticide prices and can result in high residue levels on the marketable yield. Under these conditions Integrated Pest Management (IPM) approaches are highly desirable and have been implemented in many greenhouse areas with variable success.

It has been recognised that any improvement of pest control practices at the farm level, and the development of IPM projects to solve growers' pest problems, should be based on correct knowledge and understanding of growers' perceptions of pest problems and the control options available. It is necessary to identify the key pest problems and detect the existing information gaps and needs, either at research, extension or farmers levels (Norton & Mumford, 1983; Mumford & Norton, 1984; Reichelderfer *et al*, 1984).

This thesis deals directly with this problem and tries to investigate the current crop protection situation, from the growers' point of view, in greenhouse vegetable production in Portugal as a basis for future improvements in pest control practices in this agricultural system.

In Chapter 2 a general discussion of the unique characteristics and patterns of the greenhouse industry and its development throughout the world is presented, with a detailed analysis of the consequences resulting from pests and their interactions with other components of the agricultural system.

Recently the area occupied by greenhouses in Portugal has been increasing quickly. The present area is more than 1,200 ha, vegetables occurring on at least 1,000 ha, and ornamentals on 200 ha (Chapter 3).

A descriptive analysis of the greenhouse production system in Portugal was performed, to illustrate the farm structures and growers' circumstances as well as to discuss the existing crop protection problems and strategies (Chapter 3).

Since the available data (mainly from the Algarve) reported mainly agronomic and production aspects of greenhouse crops, the situation presented in the descriptive analysis concerning pests and diseases at the farm level was not considered detailed enough. This is particularly true in the case of key pest problems and control decisions taken under the farmers' circumstances. To obtain information about the growers' decision-making process (their perceptions concerning pests and control options and how they assess the results achieved) an interview survey questionnaire of growers was done in the two major Portuguese producing areas for greenhouse vegetables: the Algarve (29 growers interviewed) and the West (32 growers interviewed). The methodological approach employed in the survey and the results obtained for both regions are discussed in detail in Chapter 5.

In Chapter 4, a review of the decision-making process in crop protection is presented, to put the approach adopted

in this thesis into context and to discuss in general the concept of decision-making and its application to crop protection problems.

One outcome of the survey work was to highlight the growers' need for more information on pest problems and current control options to improve their current practices. Since "expert systems" can improve the grower decision--making process by providing relevant information to the grower and increase his choice ability related to the available control options (Mumford, 1987), a prototype "expert system" was developed to study the viability of this approach as a practical way to provide the information requested by growers and to improve pest management decision-making in greenhouse vegetables in Portugal (Chapter 6).

Finally, the current pest control practices reported by growers and ways to improve them are summarised in Chapter 7, and recommendations are made for future research and extension activities necessary to achieve this objective.

2 - THE GREENHOUSE PRODUCTION SYSTEM

2.1 - GENERAL CHARACTERISTICS

The greenhouse production system can be characterised as an intensive agricultural system using high inputs of capital and technology (including know-how), normally on small parcels of land, which produces a large revenue per unit of land with a relatively short culture period. Labour use is also very intensive in this production system (mechanisation is limited inside greenhouses and the majority of cultural activities are by hand) but as the yield is high, the amount of labour per unit of yield remains similar (sometimes lower) to the amount required in open production systems (Dalrymple, 1973). This fact, linked with a greater revenue per unit of yield and the possibility to practice multiple cropping, explains the economic profitability of this system despite the high capital and labour costs.

The objective of this agricultural activity is to produce fresh vegetables, fruits and ornamental plants, with high quality standards, either in places where it is not possible to produce them in open fields or to produce them out of season or as early as possible in the season.

The environmental constraints to production are very distinct in different geographical areas and the greenhouses can be either sophisticated or simple

structures. These range from a glasshouse in northern Europe, with a computer-based system for environmental control and a shape to maximise radiation efficiency, which may operate with a nutrient film technique, to a high plastic tunnel or a structure with a plastic roof in the Mediterranean area. But there are some common attributes, such as crops and pest problems.

The success and expansion of this production system depends directly on the market, since prices normally fluctuate sharply through the season and the production costs per unit of yield are generally greater than in open crops. These facts, linked with the considerable initial investment in the greenhouse, make this agricultural system an unstable one and a risky business.

In the traditional greenhouse areas the success and maintenance of the industry was linked to the adoption by the growers of a "technological treadmill", involving materials and the shape of the greenhouse structure, environmental control with computer-based systems, CO_2 enrichment, nutrient film techniques, new cultivars resistant to diseases, which resulted in impressive yield increases, as Nicholson (1980) discussed for tomatoes.

However, production costs have increased, due to more and more expensive fixed resources and labour increases. Furthermore, greenhouse vegetables like many other agricultural products, have a low elasticity of demand both for income and price (Meulenberg, 1982; Nicholson, 1986).

As a result, there has been a reduction of profitability of greenhouse enterprises, with the break-even point being pushed up and up. Growers have become increasingly dependent on loan funds. Under these circumstances growers found themselves affected by inflation and interest rates. Many of them do not have the "liquidity" to cover cash--flows during unprofitable years (Nicholson, 1980; 1986).

In new greenhouse areas the rapid expansion seems to be associated with generally good income levels for growers and this fact is sometimes linked with a shift in the demand curve caused by a marked and widespread increase in income in the area or country (Dalrymple, 1973). However, as internal consumption is covered by the fast increasing supply, profits can be dramatically reduced or even disappear (Dalrymple, 1973).

2.2 - GREENHOUSE DEVELOPMENT THROUGHOUT THE WORLD

From the nineteenth century until the second World War, the greenhouse industry was mainly centred in northern Europe and in the northern states of the USA. Wooden structures were used, covered with glass, and fruit such as grapes, peaches and strawberries were important. Among vegetables, the most common crops were lettuce, cucumber and tomatoes; the last crop became a popular and important one only at the end of the nineteenth century (Dalrymple, 1973).

After the 1950's the greenhouse industry throughout the

world underwent a major change with the development of plastics for agricultural purposes and the increase of trading exchanges between countries. As a consequence, greenhouses became a very important business in new areas and, in spite of an increase in greenhouse area in countries where greenhouses were a tradition, the majority of the world area today is in the Mediterranean and in Japan, as shown in Table A in Appendix I, and consists mainly of plastic houses.

Estimates of the greenhouse acreage in the world, in 1983, indicated an area of at least 130,000 ha, with more than 110,000 ha in plastic (Garnaud, 1984; Porcelli & D'Amore, 1986) and the area covered with greenhouses continues to increase quickly.

A general perspective of the evolution of the greenhouse area by country is presented in Table A in Appendix I, based on data collected from the literature. Since the concept of "protected crops" seems to differ between authors (take for instance the example of the data collected from different sources for Spain, in Table A of Appendix I), some conflicting data was sometimes found for the same country and year, indicated by different sources. However, in spite of that fact, a general pattern in the evolution of the greenhouse industry emerges.

"Protected crops" can be defined as "...*all crops where some type of shelter is used...*" (Hussey *et al.*, 1969), or alternatively, crops where some sort of protection from the

environmental elements is achieved (Dalrymple, 1973). Nowadays this concept includes crops produced inside greenhouses and high tunnels as well as in low tunnels or any other type of shelter (Nisen *et al.*, 1988). In this work this concept will be employed in a more restricted way, meaning essentially greenhouses and high tunnels.

In Europe, and particularly in the EC, in the northern countries ornamental crops are the most important in terms of area (Denmark, West Germany, Ireland, Netherlands) while northern vegetable crops suffer increasing competition from the southern countries (France, Greece, Italy, Spain), which in spite of transportation costs are able to produce at lower cost. The evolution of crop acreages in the Netherlands and Italy represents this situation particularly well.

In the Netherlands vegetables and fruit (grapes, peaches and plums) occupied the majority of the area until World War II, but after that, and particularly after the 1960's, fruit production in greenhouses almost disappeared for economic reasons (Termohlen, 1967). Vegetable production increased until the beginning of the 1970's when it became stagnant, and then slowly decreased. By contrast, ornamentals production became more and more important after the 1960's and in 1985 this activity occupied more than 50% of the greenhouse area in the country (Table A in Appendix I).

In Italy the greenhouse industry underwent a tremendous

increase in area since 1960, mainly due to the availability of plastic, and today this country has one of the biggest protected areas in Europe. Vegetables are the most important crops and tomatoes and strawberries represent almost 50% of the total protected area of the country (Table A in Appendix I).

This changing pattern was even faster in Ireland, with vegetables, particularly tomato, being the most important crops until the mid-seventies but flowers were already the main greenhouse product in 1979 (Table A in Appendix I).

Among vegetable crops, tomato seems to be a major crop around the world, but cucumber and lettuce are also important crops in northern Europe and America. Sweet pepper has also become an important crop in some countries in those regions recently.

In the Mediterranean tomato remains one of the main crops, but melons, sweet peppers, strawberries and green beans are also very important crops. Cucumbers, lettuces, eggplants and water-melons are not generally as important as the other crops.

Recently bananas have been considered an alternative crop by greenhouse growers in some areas along the Mediterranean, particularly in Morocco and Greece, as a way to supply the internal demand for the fruit (Table A in Appendix I). Its success seems to be dependent on protectionist policies of import restrictions on bananas from major producer countries. Morocco stopped imports of

banana in 1978 and greenhouse production increased dramatically, especially after 1981, replacing the small local field production (Lasheen, 1986). In Greece, the production is based in Crete (Table A in Appendix I), where its development was also based on a small local field production. The profitability of the crop is now seriously questioned after the Greek government, under EC pressure, lifted the restrictions on banana importation in 1988 (Walston, 1988).

In Japan the main crop is strawberry, but cucumber and tomato are also very important.

Cut flowers are the major ornamental crops, particularly chrysanthemum, rose, carnation, gerbera and freesias but pot plants and bedding plants, of a wide range of botanical families, each one generally with several cultivars, are becoming increasingly important.

2.3 - THE GREENHOUSE AGROECOSYSTEM

2.3.1 - General description of the agroecosystem

The greenhouse agroecosystem can be roughly represented by the diagram in Fig. 2.1.

The components of the system are the greenhouse environmental conditions (atmosphere or soil), the crops grown inside the structure, the pest problems and the

presence and activity of beneficial organisms.

The output of the system is the marketable yield of the crops.

As the market supply has, in general, a fragmented pattern, represented by a multitude of growers who produce highly perishable goods, with little storage capacity, the individual grower has no control on market prices, which fluctuate in the short term as a function of the total marketable yield arriving at the markets.

The market, with its short-term fluctuation in prices, is a strong "external" factor affecting short and long term management decisions, linking the output and some of the inputs of the system. In such conditions, considering also the seasonal and long-term changes in demand (Folley, 1973; Dalrymple, 1973), growers must maximise the marketable yield, in quantity and quality, during the period with highest prices, in order to maximise their revenue.

The inputs of the system are essentially of two types: climate and management inputs.

The climate inputs have a direct effect on the aerial greenhouse environmental conditions and on some of the soil conditions, such as soil temperature. Not all the external climatic factors exert the same direct influence on the internal environment, particularly rain and other precipitation and wind. In some situations, as in the Philippines, one of the main objectives of greenhouse

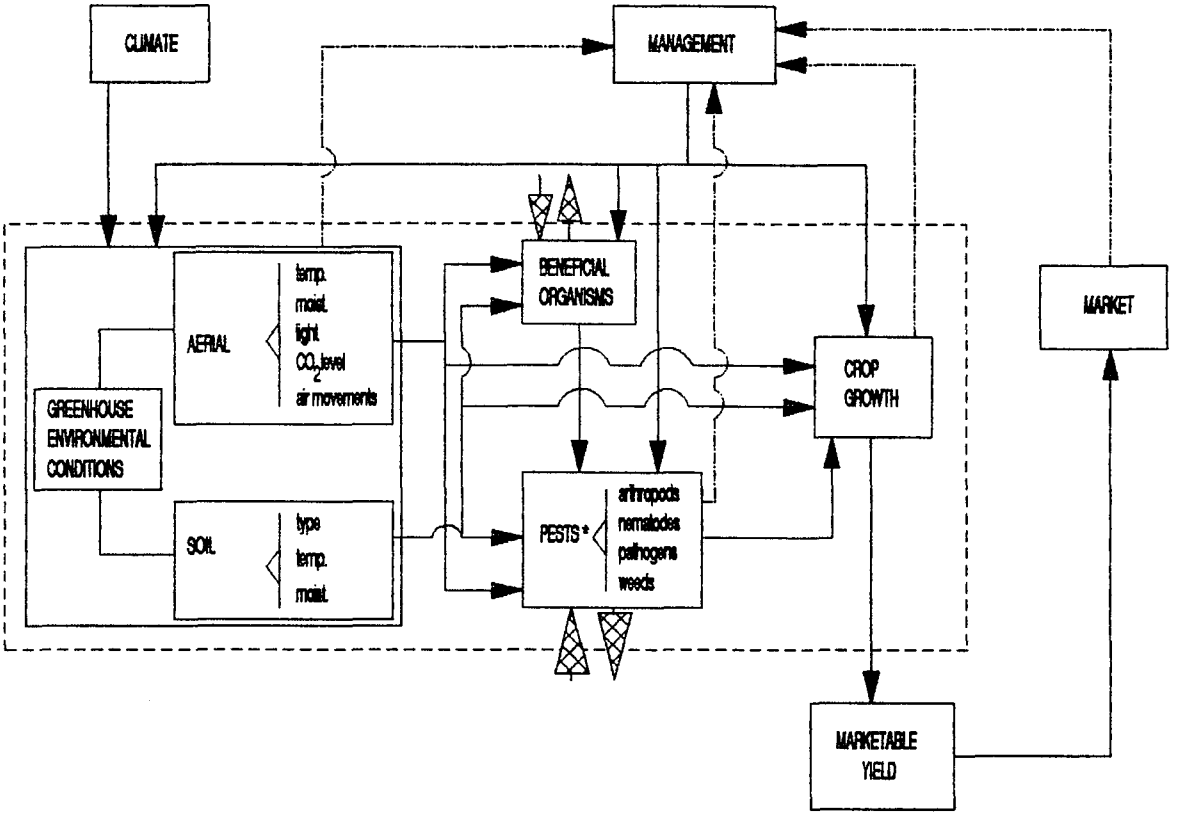
structures is to protect crops against heavy tropical rains (Dalrymple, 1973). Wind exerts a small direct effect inside greenhouses but affects ventilation, increasing the convective loss of heat (Fernando & Pereira, 1979). As a consequence, it is a major factor controlling the air temperature inside the greenhouse; the other major factors controlling temperature inside unheated plastic greenhouses are solar radiation and the soil temperature balance (Chiapale *et al.*, 1984).

The management inputs have an impact on every component of the system, and result from an interaction between the objectives and perceptions of the grower with each one of the components of the system and the system as a whole (Norton, 1982a; Mumford, 1982).

The boundary of this agroecosystem, the physical structure of the greenhouse, plays a central role in the way external climatic factors determine the internal environmental conditions. As a result, the physical structure of the greenhouse is itself subject to intensive research concerning materials, shape and orientation in order to maximise light transmission and improve the energy balance (Nisen, 1972; Spice, 1974; Winspear & Canham, 1974; Critten, 1986).

With such an effective physical boundary, the greenhouse agroecosystem has sometimes been considered as an island, from a biological point of view (Bravenboer, 1974). This position is fairly reasonable in northern Europe where

greenhouses often have resident pest populations, but in southern countries immigration and emigration of pest organisms between open field and greenhouses are normal events, made easy by large windows or other open holes in the structure.



- Natural immigration - emigration.
- Direct effects from one factor on others
- Feed-back on management
- Boundary of the system

* pest is used here in its broadest sense, meaning any damage-causing agent such as arthropods, nematodes, plant pathogens and weeds (Chiarappa *et al.*,1980).

Fig. 2.1 - The greenhouse agroecosystem

Differences in climate and in how enclosed greenhouses are in northern and southern countries can make the same crops and pest problems very different in each region.

2.3.2 - Interactions in the agroecosystem

According to Walker *et al.*(1978), the description of the dynamic properties of a particular ecosystem must consider the changes in the ecosystem components over time and the principal pathways and flows through the ecosystem.

Since in this agroecosystem the changes in the components over time, like main crops, crop season length, crop sequences, new cultivars, new techniques, new pest problems, resistance to pesticides, vary from place to place and from region to region, this section of the descriptive analysis mainly concerns the analysis of the principal pathways and flows through the agroecosystem, which are independent of location.

To do that an interaction matrix was constructed (Fig. 2.2), in which the components of the ecosystem and its management inputs, as well as the external market, are listed as columns and rows, using the analytical technique described by Walker *et al.* (1978) and Norton & Walker (1985).

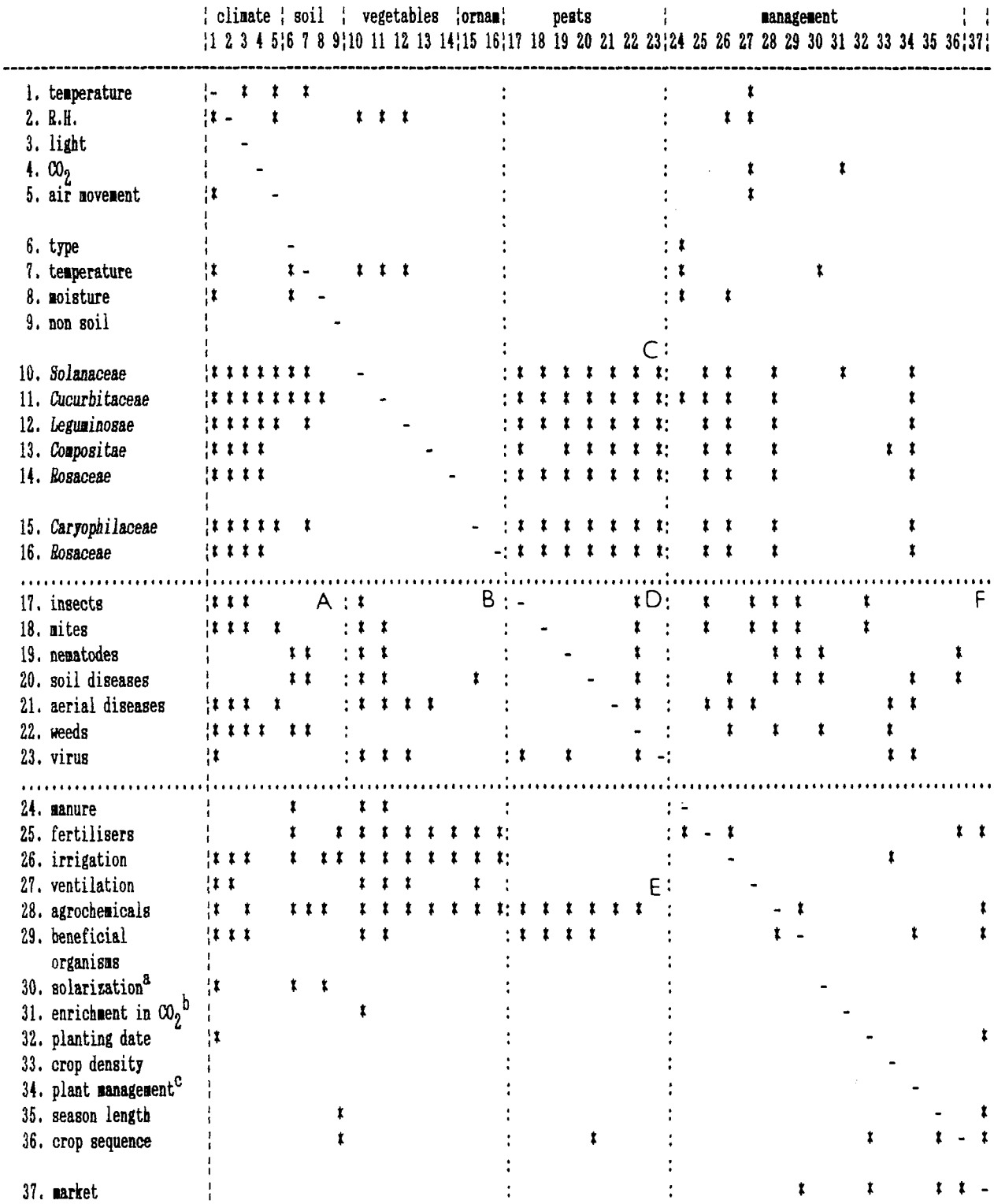
To illustrate how the interaction matrix works the effect of the first component considered (air temperature) on the

other components directly affected by it is briefly discussed. Furthermore this component is dependent on insolation, air movement and ventilation rate inside greenhouses and energy balance at the soil level (soil temperature).

Relative humidity is the ratio of the actual vapour pressure to the saturation vapour pressure at a given temperature and since saturation vapour pressure increases exponentially with an increase in temperature (Rosenberg, 1974), temperature affects the relative humidity in an inverse way.

If the ambient air temperature outside greenhouses is colder than the air temperature inside, the interior surface of the material covering the greenhouse can have a temperature lower than the dew-point temperature of the air inside the greenhouse and condensation occurs along the coldest areas of the internal surface. In plastic greenhouses this phenomenon is very frequent and water condenses in small sphere-like droplets along the plastic film, which do not spread over the surface but drop onto the plants (Semedo, 1979); by contrast, on glass surfaces droplets tend to slide down the glass, rather than dropping off.

Dew formation can also occur on the plants when their temperature drops below the dew-point.



a- solarization is important where temperature is sufficiently high for the process, as in the Mediterranean area.

b- this factor is important where the boundary of the system is sufficiently tight, as in the northern European countries.

c- plant management means: sowing, transplanting, pruning, training, pollinating, deleafing, harvesting and removing and destroying plant debris.

Fig. 2.2 - Interaction matrix showing the main interactions inside the greenhouse agroecosystem. (Each * denotes an effect of the column factor on the row factor.)

The effect of temperature on air movement inside greenhouses is the result of differential heating of the air between different areas inside greenhouses caused by differential exposure to solar radiation of different sides of the structure. Furthermore, the patterns of air movement inside greenhouses will be dependent on the height and density of the plants occurring in the greenhouse. Finally, the difference in air pressure between the air inside and outside greenhouses, caused by difference in temperatures, is responsible for an air current through the doors, windows or any other opening on the structure, which results in the replacement of the air inside greenhouses (natural ventilation) (Frinking & Scholte, 1983).

The effect of air temperature on soil temperature depends either on the type of soil (soil specific characteristics like density, porosity, moisture content, organic matter, colour) or on the characteristics and colour (which define the thermal properties) of the mulching materials covering the soil (Rosenberg, 1974; Katan, 1981). Since soil temperature plays an important role in the energy balance inside greenhouses as well as on the initial development of the plants, this interaction can be an important one, particularly in unheated greenhouses.

Temperature affects the moisture content of the soil since it controls the evaporation rate of soil water, which could be a major source for the air moisture content inside greenhouses, specially in the first phase of the crop when the seedling canopy does not cover the soil.

The effect of temperature on crops is at different levels: it affects the photosynthetic rate either of the plant or of the crop canopy and affects the growth and development rates of vegetative and reproductive organs, as well as the transpiration rate of the plants which is a major source of air moisture inside greenhouses. Therefore it is possible to define the minimum and maximum temperatures for growth, as well as the optimum temperature for each plant species and even for each cultivar.

Among *Solanaceae*, for tomato the optimum temperature range for vegetative growth is between 18° C and 25° C and higher temperatures favour vegetative growth instead of flowering whereas lower temperatures reduce vegetative growth more than flower development (Picken *et al.*, 1984). Extreme temperatures limit fruit set: temperatures below 10° C or above 30° C affect one or more of the processes leading to fruit set (Picken, 1984).

Sweet pepper has higher temperature requirements than tomato, but its optimal temperature decreases as the plant develops (Monteiro & Portas, 1986). At 10° C vegetative growth is very limited (Fletcher, 1984). Aubergine grows at temperatures around 20° C (Fletcher, 1984).

For *Cucurbitaceae*, temperature is the most important climatic factor on anthesis and anther dehiscence; optimum temperature for dehiscence of pollen sacs is between 18° C and 21° C either in water-melon, cucumber and gherkin or in melon (Whitaker & Davis, 1962). The optimum temperature

for germination of cucumber is 27° C and the crop is grown, in the U.K., at a temperature of 21° C during the day and 19° C at night (Fletcher, 1984).

For *Leguminosae*, the optimum temperature for flowering and pod setting is between 15° C and 25° C (Inoue & Suzuki, 1959). Under low temperatures, or under high temperatures, the ovule or zygotic viability can be drastically affected and, as a consequence, the number of seeds per pod is reduced; since no pod tissue development occurs in the vicinity of aborted ovules, the pods present irregular growth and curling (Farlow *et al.*, 1979).

In the *Compositae*, lettuce is the greenhouse crop which tolerates lower temperatures, and commonly used temperatures in the U.K. are 4° C at night and 10° C during the day (Fletcher, 1984).

For *Caryophilaceae*, carnation crops do not require high temperatures, and in the U.K. the commonly used temperature is around 12° C (Fletcher, 1984).

For *Rosaceae*, roses are grown, in the U.K., with low temperatures in winter (8° C at night and 10° C during the day) and higher temperatures in summer (16° C at night and 18° C during the day) (Fletcher, 1984).

The effect of temperature on insect pests is illustrated by a few examples. The duration of life cycle of the glasshouse whitefly (*Trialeurodes vaporariorum*) varies from 123 days, at 12° C, to 18 days at 30° C and the total

number of eggs produced is highest at 21° C (Stenseth, 1985). For *Thrips tabaci* the duration for development from egg to adult stage is 16.1 days at 25° C and 11.2 days at 30° C; under fluctuating temperatures with an average of 30.8° C the duration of development is 13.9 days (Lewis, 1973). The oviposition process of thrips is also affected by temperature and for *Heliothrips haemorrhoidalis* the temperature threshold for egg laying is 12.5° C with the number of eggs laid at the range 15.5-20° C being 25 eggs while at the range 25.5-28° C the number of eggs laid is 47 (Lewis, 1973).

For *Helicoverpa armigera* the duration of development for the larval instars varies between 47.3 days at 15° C to 9.5 days at 30° C and the duration of its pupal instar varies from 33 days at 20° C to 12 days at 30° C (Balachowsky, 1972).

The effect on mites is shown by the two-spotted spider mite (*Tetranychus urticae*), whose life cycle varies from 30 days at 15.5° C to 3.5 days at 32° C (Scopes, 1985), with the temperature threshold for development at 12° C and maximum temperature for development about 40° C, the temperature range between 30-32° C being the optimum temperature for development (Jeppson *et al.*, 1975).

The effect of temperature on aerial diseases can be observed in several biological processes like mycelial growth, spore production and spore germination and this is illustrated with a few examples.

The approximate temperature range for growth of *Phytophthora infestans* is <5-28° C (Weste, 1983) with the optimum temperature for growth at 20° C (Waterhouse *et al.*, 1983). Sporangia can be produced by the fungi within the temperature range of 3-26° C, with the optimum temperature for the the sporangium formation process between 18-22° C (Ribeiro, 1983). Temperature is also a major factor controlling the subsequent evolution of the sporangia: a) if temperature is around 12° C (temperature range of 9-15° C according to Webster (1980)) zoospores diferentiate inside the sporangium and the duration of their motility after being released from sporangia is also temperature dependent, changing from 22 hr. at <10° C to 30 min. at 16--25° C; b) if temperature equals or is higher than the optimum for mycelial growth the sporangium germinates and develops a germ tube, which as an optimal temperature for development at 24° C (Ribeiro, 1983).

Botrytis cinerea has an optimal temperature for growth between 20 and 25° C (Blakeman, 1980). However, the fungi can grow abundantly between 8 and 16° C (Palti, 1981) and in stored products its mycelium has been found growing at any temperature above 0° C (Jarvis, 1980b).

Epidemics of *Leveillula taurica* on tomato can be expected within the temperature range of 15-25° C (Fletcher, 1984).

The effect of air temperature on weeds is the same as described above for the interaction between temperature and crops.

Temperature can have a direct effect on the activity or virulence of some plant viruses, as Bos (1983) indicated for Tobacco Mosaic Virus (TMV), which produces only local lesions in *Nicotiana glutinosa* if temperature is lower than 30° C but causes vascular necrosis and plant death if temperature rises above 30° C.

Another direct effect of temperature on virus is used as a biological property to characterise viruses (the thermal--inactivation point) and is intended to "*describe the persistence of infectivity of viruses in expressed sap* (for a given temperature)...*being done by heating for 10 minutes at a range of temperatures, usually at intervals of 5° C from about 45° C to 90° C*... (Bos, 1983).

The amount of water necessary to the plant through its development is mainly dependent on the solar radiation level (Rudich & Luchinsky, 1986) and, consequently, temperature is one of the climatic factors affecting the transpiration rate of plants inside greenhouses and determining the irrigation requirements of the crops.

As a result of the thermal properties of the materials employed to cover greenhouses, the temperature inside greenhouses is higher than outside. However, temperature can rise to excessive values and to keep the temperature within desirable limits it is necessary to ventilate the greenhouse, changing the air inside with cooler air from the outside. The ventilation rate is mainly dependent on the difference of air temperature inside and outside

greenhouses and this rate would increase as far as the temperatures outside and inside the greenhouse become similar (Hanan *et al.*, 1978; Monteiro, 1983).

Modern pesticides are normally stable under normal environmental temperatures. However, temperature can affect the efficacy of some of them and/or the phytotoxic effects of the pesticide on the crops. This interaction is illustrated with a few examples (Ivens, 1988): sulphur, which is used inside greenhouses in many areas as a fungicide and acaricide, should not be applied if temperature is around 30° C or above, for phytotoxic reasons; deltamethrin may have reduced effectiveness or persistence if temperature is above 35° C; temperature above 30° C may reduce the efficacy of pyrazophos and dimethoate; below 15° C pirimicarb has little vapour activity which implies that a good coverage of the crop is essential under cool weather; dinocap should not be applied if temperature is above 24° C for phytotoxic reasons.

The effect of temperature on beneficial organisms assumes the same patterns as for pests since the beneficial organisms employed in biological control in greenhouses are mainly arthropods or fungi (Table B in Appendix I).

For arthropods temperature affects development rate, reproductive rate and behaviour. The example of *Encarsia formosa* illustrates well these aspects: the developmental period varies from 52-56 days at 25° C to 10-16 days at 30° C, the longevity of the imagos varies from 47.7 days at

15° C to 6 days at 30° C and the fecundity presents the highest values at 25° C, being severely reduced at 30° C (Lenteren & Hulpas-Jordaan, 1983). These authors claimed that the imagos could already fly at 13° C although flight became more common at 17-18° C. Another example is the predator mite *Phytoseiulus persimilis* whose total development period varies from 19 days at 15° C to 7 days at 27° C (Stenseth, 1979a) and this mite does not develop above 30° C (Scopes, 1985). Temperature is also one of the most important factors affecting the period of time necessary to control two-spotted spider mite (*Tetranychus urticae*) by *P. persimilis* (for a *T. urticae/P. persimilis* ratio of 100:1 the necessary time for control is 40 days at 13° C, around 25 days at 18° C and around 13 days at 24° C) (Scopes, 1985).

For fungi, the growth rate and sporulation processes as well as the germination of conidia are affected by temperature. The strain of *Verticillium lecanii* studied by Ekbom (1979) had an optimal temperature for mycelium growth at 26° C while for sporulation and germination of spores temperatures around 24° C were the most convenient.

Soil solarization (..."*a special mulching process* (done with a thin transparent plastic sheet) *which causes hydrothermal disinfestation and other physical and biological changes in soil which are beneficial to plant health and growth ...*" (Stapleton & DeVay, 1986)), should be done during the period of the year with high air temperatures (25-26° C as the average daily air temperature

in the Israeli experiments) and high values of solar radiation (600-650 ly/24 hr. under Israeli conditions) (Katan, 1981) since the energy balance between the atmospheric boundary layer and the upper soil layer radiation is dependent on incoming flux of longwave radiation and the global radiation of the place amongst other factors (Mahrer & Katan, 1981). Through this process an increase in soil temperature is achieved (around 10° C in the upper layer of the mulched soils when compared with bare soils) resulting in reduced inoculum densities for several plant pathogens and on the numbers of viable seeds for many weeds (Katan, 1981; Stapleton & DeVay, 1986).

Finally, temperature fluctuation on a seasonal basis plays an important role in the establishment of planting and cropping schedules of greenhouse crops (van de Vooren *et al.*, 1986).

Through this process it is possible to analyse as deeply as necessary each interaction, review the information already published on that subject and detect knowledge gaps about specific problems. Other interactions are not discussed in detail one by one.

2.3.3 - Pest problems in greenhouse crops

Since pest problems are of special concern in greenhouses (pests are the only component of the system whose effects

must be minimised, all the other components are things to be maximised or optimised), the sub-system "*Pest problems of greenhouse crops*" will be considered and analysed in a more detailed way.

The sub-system is represented in Fig. 2.2 inside the dotted lines and the interactions inside the sub-system can be put into six distinct groups (matrix cells from **A** to **F**).

1. The effect of microenvironmental conditions on the pests can be considered (aerial climatic conditions for aerial pest problems and soil environmental conditions for soil pest problems) and how they can be changed in order to reduce the negative contribution of this sub-system to the output of the greenhouse agricultural system (matrix cell **A** in Fig.2.2).

Several approaches have been tried to make environmental conditions inside greenhouses unsuitable for pest problems. The environmental control achieved with computer-based systems reduced the importance of air-borne diseases, particularly those fungi whose development is dependent on high humidity or free water films on the plant surfaces (like downy mildews (late blight), grey mould, leaf mould, rusts...) (Fletcher, 1984). However, as this author stated, low relative humidity conditions seem to favour powdery mildews.

Other techniques employed are linked with the physical boundary of the greenhouse itself, either trying to seal

the greenhouse surface to the outside environment through insect-proof nets fixed along the windows, which also reduces the ventilation rate (Nisen *et al.*, 1988) (in spite of this, Tommasino *et al.* (1985) reported that temperature and relative humidity were not adversely affected); or changing the absorption properties of the material covering the greenhouse frame (in Japan, UV-absorbing vinyl films were efficient to reduce the sporulation of grey mould on cucumber and tomato (Honda *et al.*, 1977) and in other experiments this technique was also efficient against *Sclerotinia* disease on cucumbers (Honda & Yunoki, 1977) and early blight (*Alternaria solani*) on tomato and sweet pepper (Sasaki *et al.*, 1985)).

Several techniques have been employed to modify the soil environmental conditions to control soil pest problems. Steam sterilisation was widely used in northern Europe until recently to control soil-borne pests, based on the lethal effect of high temperatures associated with moist conditions in the soils (Fletcher, 1984).

The research workers who developed solarization took advantage of the same effect of high temperatures and moisture in the soil, using solar radiation, but because temperatures do not reach such high values as in steam sterilisation, 4 to 6 weeks are usually necessary to achieve good results in deeper layers of the soil (Stapleton & DeVay, 1986).

The most drastic attempt to control soil environmental

factors affecting pests consists of the complete elimination of soil, and the utilisation of the nutrient film technique is a good example of the sophistication obtained. Unfortunately this technique is not exempt from disease problems (Graves, 1983; Winsor *et al.*, 1985).

2. The effect of crops on pest problems is represented in the matrix cell B in Fig. 2.2.

The actual feeding of invertebrates on plants is the result of several factors including repellence/attractiveness of the plants based on colour or volatile compounds produced by secondary metabolites, toxic compounds on the plant, the thickness and hairiness of plant surfaces, how hungry the animal is and in some cases even its previous experiences.

As a consequence of such complex relations each crop is generally attacked by a small number of species and according to the suitability and nutrient value of the host plant the longevity and fecundity of pests can be deeply affected. An example of the effect of different host plants (aubergine, cucumber, tomato, sweet pepper) on longevity and fecundity of glasshouse whitefly is provided by Woets & Lenteren (1976) and the effect of ageing and nutrition of tomato plants on fecundity of glasshouse whitefly is given by Hussey & Gurney (1960).

The infectiousness of pathogens to their hosts is dependent on the immunity or susceptibility of the host, which varies from plant species to species and even from

cultivar to cultivar, and on the virulence and/or aggressiveness of the pathogen. Plant breeding through the introduction of genes for resistance in the host reduces its susceptibility to low values (nil in vertical resistance when not in presence of the compatible virulent race or strain of the pathogen) and because of that resistant cultivars are regarded as a very effective way to fight pest problems until the virulent strain becomes predominant in the environment. However, the virulent strains can evolve very fast, making the plant breeding work a complex and endless job.

In greenhouse crops resistant cultivars against several strains of some major pest problems are available, particularly for tomatoes, and even biological control programs against glasshouse whitefly in cucumber crops were improved by breeding glabrous cultivars of this crop (Ponti, 1980; Lenteren *et al.*, 1987).

3. The effect of pests on crops is considered in matrix cell C in Fig. 2.2.

This deals with the relation between yield and infestation levels. Clearly, the action of pest problems on plants induces damage, which sometimes can be compensated by the plants but usually if the pest problem is allowed to continue without control result in a reduction of marketable yield, which can be total.

Crop loss assessment studies are particularly important to

determine: a) which yield components are most affected by the pest problem; b) what is the relationship between infestation levels of the pest and yield losses on the crop; and c) to help define pest control strategies which are economically sound and environmentally desirable. In spite of the complexity and difficulty involved in crop loss studies, some work has been done to quantify the action of several pest problems in greenhouse crops and a few examples are discussed briefly.

Glasshouse whitefly (*Trialeurodes vaporariorum*) can affect tomato yields directly, through sap intake, or indirectly by honey-dew production which is used as a nutritional substrate by sooty moulds, reducing photosynthesis and causing cosmetic depreciation of the fruits. This latter effect is much more important in terms of depreciation of the fruit for a particular infestation level and Hussey *et al.* (1959) indicated that infestation levels in the upper leaves of the order of 3.5 "scales" (immature stages of the insect) cm^{-2} caused some loss from sooty moulds; by contrast only infestation levels of the order of 25 "scales" cm^{-2} reduced the yield. As a conclusion of their work Hussey *et al.* (1959) proposed that the average number of "scales" in the upper leaflets should not exceed 7 "scales" cm^{-2} and Scopes & Ledieu (1979) indicated a "threshold level" of 18 adults per leaf in the upper leaves ("threshold level" considered here in the sense referred to by Bardner & Fletcher (1974) as "...*the pest population level below which no damage is detectable...*"; this concept

was redefined later by Chiarappa (1981) as the "critical level" ("...*the maximum level or intensity of pests or other constraints at which crop damage has not yet occurred but is expected to occur soon...*)).

Alomar (1984) worked out both values and concluded that they were equivalent and in agreement with the results of his own experiments for the losses due to sooty-moulds. However, his experiments on yield losses caused by glasshouse whitefly suggest that loss is proportional to whitefly numbers without any "threshold level", which contradicts the results of Hussey *et al.* (1959) reported above. Unfortunately the results presented by Alomar (1984) do not give a clear idea about the relation between yield and infestation level at low densities of the pest, exactly where the contradiction exists between both works.

The yield components affected by glasshouse whitefly seem to be mainly the number of fruits per truss (Hussey *et al.*, 1959; Lindquist *et al.*, 1972), though the former work gave some indication that the size of the fruits may also be reduced.

Two-spotted spider mites (*Tetranychus urticae*) can cause severe problems in greenhouse crops by piercing the leaf tissues when feeding. Hussey & Parr (1963) established the "threshold level" on cucumbers as 30% of the total leaf area damaged by the pest (corresponding to the value of 1.9 on a "damage index" scale defined by the authors). On tomatoes the "threshold level" was considered to be 33% of

leaf area damaged by the pest, corresponding to a "damage index" of 2, according to Scopes & Ledieu (1979), this value being later indicated by Scopes (1985) as about 30% of the photosynthetic area of the plant. If those values were exceeded yield reductions would be expected some time later (5 weeks in cucumber, the time necessary for the development of the fruit (Hussey & Parr, 1963)).

Stacey (1983) tried to simulate the effects of leaf pests on tomato by defoliation of the plant and concluded that the plant could tolerate a reduction of 25% of the leaf area without suffering yield losses. However, Wyatt *et al.* (1984) reported that they found a straight line response between % of leaf damage caused by two-spotted spider mites and yield loss, with each 10% increase in leaf area damaged on the twelve upper leaves of the plant resulting in a reduction of 8.5% in the number of fruits, the effects on yield being visible 38 days after the occurrence of the damage. Nevertheless, this work does not indicate any "threshold level", suggesting that any infestation level of the pest will cause yield loss which contradicts the previous experimental and simulation evidence of plant tolerance to lower infestations of this pest.

The yield component affected in both tomato and cucumber crops is the number of fruits, their size being apparently unaffected (Hussey & Parr, 1963; Wyatt *et al.*, 1984). For the tomato crop the results of the artificial defoliation pointed out exactly the same effect, being the number of fruits the yield component affected (Stacey, 1983).

The tomato leafminer *Liriomyza brioniae* is another leaf feeder which reduces the total leaf area of the plant and whose effects have been studied. Wyatt *et al.* (1984) found a linear relation between the infestation level on the six leaves surrounding a truss when the fruits on that truss were half grown and the final yield obtained on the truss, with an average loss of 10% caused by an infestation of 30 mines per leaf and 20% loss if the infestation level reaches 60 mines per leaf, suggesting no apparent "threshold level" below which there is no loss (Ledieu & Helyer, 1985). This is in contrast to previous results assessing this value at 15 mines per leaf (Ledieu & Helyer, 1982) and with the simulation study by Stacey (1983) who concluded that 25% of the leaf area could be destroyed without yield reduction. Like in the previous examples there are some conflicting data about the effects of low infestation levels on yield. However, in this case the yield component affected by the pest seems to be the size of the fruits and not their number (Wyatt *et al.*, 1984; Ledieu & Helyer, 1985).

The effect of corky root rot (*Pyrenochaeta lycopersici*) on tomatoes was studied by Ebben & Last (1975) and Polley (1985). Both works found a relation between disease severity, assessed 8 weeks after planting, and yield reduction. Ebben & Last (1975) studied the effect of low infestation levels and for values below 20% of disease severity they found a yield reduction of 1.4% for each 1% increase in disease severity. Some of the results obtained

by Polley (1985) agree with the previous study but, according to this author, the increase in yield loss would be 0.35% for each 1% increase in disease severity, particularly for infestation levels above 20%, which supports the existence of a non linear relationship between corky root rot severity and yield reduction. In fact, the author got a better fit for the experimental data using an exponential function, emphasising the bigger impact per unit of disease increase in the loss expression when in the presence of lower amounts of disease early in the season. Furthermore this relationship seems to change with soil type and conditions.

According to the results indicated by Polley (1985), the yield components affected seem to be both the number of fruits and the size of the fruits.

4. Matrix cell D in Fig. 2.2 deals with the importance of weeds, inside or outside greenhouses, and with virus vectors.

Weeds are reservoirs or alternative hosts for many pests and pathogens, emphasising the importance of weed control in order to obtain a reduction in the initial amounts of inocula or arthropod numbers.

Furthermore, the role played by some arthropods and nematodes as virus carriers is also illustrated, and in those cases any reduction on the epidemiological importance of the vectors is highly desirable resulting in control

measures adopted against the vectors.

5. The effect of pests on some management actions is represented in matrix cell E in Fig. 2.2.

The interactions represent mainly the effect of the pest problems on the choice of pesticides and biocontrol agents.

Pesticides are usually approved to be used on a particular crop (or group of crops) to control specific pest problems, clearly indicated on the label, based on the study of biological efficacy and toxicological hazard presented by any particular formulation.

Therefore, growers must comply with the conditions of approval, with any unapproved application being a legal offence. However, the legislation is usually only enforced sporadically, through studies of pesticide residues present in crop products collected along the food chain, and these studies are non-existent in many countries. So, the potential for the offence is there, since the grower may be tempted to consider the biological efficacy of the pesticide for a particular pest problem irrespective of the crop if he is confronted with high risks and an unapproved pesticide is perceived to be highly effective against the hazard agent. Nevertheless, the grower usually selects the pesticides he needs to apply from amongst the approved ones for each particular pest- crop situation.

The occurrence of resistance to the commonly used pesticides in northern Europe in the 1950's and 1960's

encouraged the development of biological control against some pests, particularly spider mites and whitefly. The results achieved were successful and this method of control spread quickly through northern Europe and was extended against other pest problems (Table 2.1).

Table 2.1 - Evolution of biological control in greenhouses since 1968 (data from western Europe, mainly) (Lenteren, 1987).

year	1968	1970	1973	1976	1979	1982	1985
Number of natural enemy producers	1	1	2	5	5	15	15
Number of countries with applications of:							
Encarsia spp.		3	3	9	11	15	18
Phytoseiulus spp.	2	2	3	11	11	15	18
Aphidoletes spp.					1	1	2
Dacnusa spp./ /*Opius* spp./ /*Diglyphus* spp.					1	3	8
Amblyseius spp.						1	3
Verticillium spp.						1	1
Area (ha) in which application occurs	10	325	540	1600	2040	2260	3000

A general perspective of the evolution of biological control is presented in Table B in Appendix I.

The adoption of biological control created other constraints on the selection of pesticides to be applied

inside greenhouses since the side effects of the agrochemicals on the biological control agents can affect the performance of the beneficial organisms (Hassan, 1985; Hassan & Oomen, 1985; Ledieu, 1985; Hassan *et al.*, 1987).

The remaining interaction represented in this group reflects the harmful effect caused by the build-up of soil--borne pathogens on the crop sequence, making it impossible to grow some highly profitable crops and explaining the need for technically sound rotations or crop sequences when possible and economically feasible.

6. The effects that normal cultural actions can have on the pest problem's intensity are discussed in matrix cell F in Fig. 2.2.

This illustrates how management inputs can be used to improve cultural control of pest problems.

Fertilisers are one of the inputs which can affect the intensity of pest problems, through a change in susceptibility of the host tissues or their nutritional value. However, this effect depends either on the specific form of nitrogen applied (for example, the development of *Verticillium* wilt (*Verticillium albo-atrum*) on tomato is favoured by applications of nitrate nitrogen, while *Fusarium* wilt (*Fusarium oxysporum* f.sp. *lycopersici* is inhibited by nitrate nitrogen and favoured by applications of ammonium nitrogen (Palti, 1981)) or the pathogen involved (high rates of fertiliser application, specially

nitrogen, seem to increase the severity of tomato late blight (*Phytophthora infestans*) (Schmitthenner & Canaday, 1983) whereas *Fusarium* wilt is favoured by low levels of nitrogen in the soil (Jones & Woltz, 1981) and high levels of nitrogen in the soil decrease the incidence of grey mould (*Botrytis cinerea*) (Verhoeff, 1968)).

The effect of high levels of nitrogen on the increase of reproductive capabilities of two-spotted spider mite (*Tetranychus urticae*) have been reported by several studies and for different hosts, including tomato (van de Vrie *et al.*, 1972).

Irrigation techniques can have an important impact in the spread of some pathogens. Overhead sprinkler irrigation is regarded as a possible control method for tomato powdery mildew (*Leveillula taurica*) where environmental control is practised (Fletcher, 1984). However, if downy mildews are present in greenhouses, the wetting of the foliage and splashing of the inocula caused by overhead irrigation increases the risk of high infestations. Sirjacobs *et al.* (1986) studied the effect of different irrigation systems (furrow, sprinkler and drip) on the propagation of pepper blight (*Phytophthora capsici*) in Morocco and concluded that the lowest levels of disease propagation were associated with drip irrigation.

The need for ventilation inside greenhouses makes the movement of arthropods between inside and outside greenhouses very easy, allowing repeated establishment of

initial foci of arthropods and air-borne diseases, creating the necessity for constant or very frequent monitoring of pest problems. On the other hand, the existence of large openings along the surface of the greenhouse allows an easy escape of parasitoids or predators employed as biocontrol agents, obliging the release of higher densities of beneficial arthropods, particularly if the greenhouses have a dispersed geographical pattern.

The use of control methods on the crops (represented in the interaction matrix by pesticides, biocontrol agents and solarization) is intended either to reduce the actual populations of pests to non-significant economic levels or to prevent the establishment of pest propagules on the crops.

The efficacy of control methods is usually widely demonstrated before they become adopted by the growers' community (pesticides go through an approval scheme where efficacy is shown before the product is cleared; beneficial organisms tend to be evaluated for their ability to reduce or suppress pest populations through practical experiments before they become available or released; solarization has been researched in appropriate weather conditions, to establish which pathogens and weeds are effectively controlled).

However, some undesirable effects are associated with the use of pesticides, like the existence of residues on crops, the occurrence of pest resistance to pesticides, the side

effects of pesticides on non-target organisms and the phytotoxic effects on the plants resulting in yield losses. All these effects create difficulties, some being real threats to the greenhouse industry, and justify other control approaches.

By contrast, biological control avoids these problems but is dependent on the availability of sufficient biocontrol agents when necessary. Its success is also dependent on the side effects of the pesticides applied against other pest problems inside greenhouses and on the environmental conditions inside greenhouses, since foraging behaviour of parasitoids and predators varies according to temperature and/or moisture values inside greenhouses.

Planting date and crop density of greenhouse crops are mainly dependent on economic and market factors, if temperature and light requirements of the crop become fulfilled. However, the planting date and crop density can be very important from a crop protection point of view, since greenhouse crops can provide continuity for pest populations from field crops, or can provide ideal conditions for the development or spread of diseases through a dense canopy.

Plant management can result either in the spreading of pathogens within the greenhouse or between greenhouses or in the production of wounds on the plant surface which facilitates infection by pathogens. For example, the utilisation of an electric truss vibrator to increase the

fruit setting of the first trusses in tomato is regarded as a very efficient inoculation method for Tomato Mosaic Virus (TMV), if any plant in the greenhouse is infected (Termohlen, 1967). *Didymella* stem rot (*Didymella lycopersici*) can easily be spread by greenhouse workers through handling tomato plants during pruning or training activities (Fletcher, 1984) or by plastic twine used to support the tomato plant in the training system which had been used in previous seasons and became contaminated (Blancard, 1986). Grey mould (*Botrytis cinerea*) spores can enter tomato stems through wounds resulting from deleafing and after some time they germinate and produce stem lesions (Verhoeff, 1980).

Finally, crop sequence can be responsible for the build-up of soil-borne pathogens to such levels that a crop becomes unprofitable. In spite of that, the lack of alternative crops in economic terms can induce growers to repeat a particular crop for several consecutive seasons in the same greenhouse until the amount of pest propagules reaches such levels that the crop output is seriously affected.

3 - PROTECTED CROPS IN PORTUGAL

3.1 - HISTORICAL DEVELOPMENT

Protected horticulture began in the southern province of the country (Algarve), near the border with Spain, in the late 1950's, but by 1972 there was only about 11 ha of greenhouses. During the 1970's an increased internal demand for out of season vegetables, and the development of the plastic industry in agriculture, caused the area of greenhouses to spread west through the Algarve province, reaching an area of 685 ha in 1986 (Table 3.1).

Table 3.1 - Evolution of greenhouse area in the Algarve.

year	area(ha)	source
1972	11	Vargues, 1979
1973	24	Barradas *et al.*, 1979
1974	52	Vargues, 1979
1975	59	Barradas *et al.*, 1979
1976	95	Vargues, 1979
1977	147	Barradas *et al.*, 1979
1978	247	Vargues, 1979
1979	429	I.N.E., 1982
1982	500	Monteiro, 1983
1984	600	Monteiro, 1984
1986	685	Fonseca *et al.*, 1986

In this region there are also 1,450 ha of soil protected with plastic mulching for strawberry, melon and water-melon crops and 30 ha of low plastic tunnels with strawberries and melons (Fonseca *et al.*, 1986). Further north, near Lisbon, the protected crops spread after late 1970's, with

vegetables in a region NW of Lisbon (West) and flowers mainly in an area E-SE of Lisbon. The evolution of the greenhouse area in this region has been very fast, as shown in Table 3.2.

Table 3.2 - Evolution of vegetable greenhouse area in the West

year	area(ha)	source
1982	120	Palma *et al.*, 1982
1985	200	Canha, 1985

In this region, near Lisbon, there are also 2,000 ha of soil protected with plastic mulching for melons, strawberries and water-melons and 50 ha of low plastic tunnels for tomato seedlings for the tomato paste industry (Fonseca *et al.*, 1986).

Table 3.3 - Estimated area of greenhouses in Portugal (Fonseca *et al.*, 1986).

Regions	vegetables (ha)	%	ornamentals (ha)	%	total (ha)	%
Entre Douro e Minho(North litt.)	30	3	20	10	50	4
Beira Litoral (litt. Centre)	15	1.5	10	5	25	2
Ribatejo-Oeste (around Lisbon)	300	29.5	160	80	460	38
Algarve (South)	675	66	10	5	685	56
TOTAL AREA	1,020	83.6*	200	16.4*	1,220	

(* - % values related to total area)

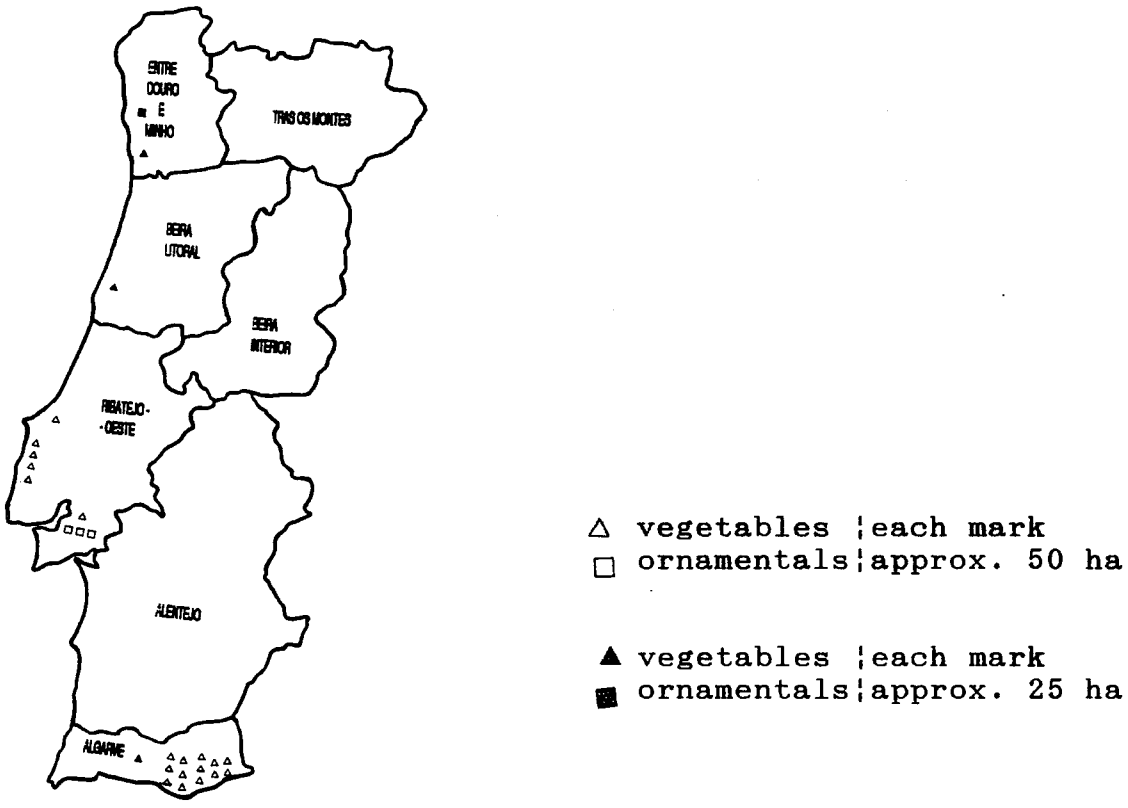


Fig. 3.1 - Location of the main greenhouse areas in Portugal (Monteiro *et al.*, 1988).

In 1986 the area of greenhouses in Portugal was estimated to be about 1,200 ha (Table 3.3), located as shown in Fig. 3.1.

Palma *et al.* (1982) estimated that a greenhouse area of 1,500 ha would be necessary to cover the internal demand for good quality fresh vegetables out of season and further increases should be dependent on export capabilities. Otherwise, if supply exceeds the internal consumption the industry's profits can be jeopardised, as discussed in Chapter 2.1. With these prospects in mind there is still plenty of room for the current expansion phase of the industry but a gradual reduction in profits should be

expected.

The production of ornamentals in greenhouses is especially important around Lisbon (80% of the total ornamental area) and the recent increase of the area occupied with ornamentals in the country is considerable (Table 3.4).

Table 3.4 - Evolution of ornamentals greenhouse area in Portugal.

year	area(ha)	source
1970	81	Dalrymple, 1973
1975	104	Louro *et al.*, 1975
1980	95	Lança, 1985
1982	162	Lança, 1985
1985	191	Lança, 1985
1986	200	Fonseca *et al.*, 1986

3.2 - FARM STRUCTURE

In the beginning of this agricultural activity most greenhouse enterprises, in the Algarve region, were small holdings of less than 1 ha (Table 3.5), but the average area has been increasing and nowadays 45.1% of the holdings have an area between 1 and 4 ha and represent 32% of the greenhouse area; furthermore 5.5 % of the greenhouse enterprises have an area bigger than 25 ha and represent 16% of the greenhouse area in the region (Zettelmeyer & Henriques, 1986). In the West region the size of the enterprises is smaller than in the Algarve region. The majority of the holdings have less than 1 ha and the biggest holdings are less than 5 ha, on average.

Table 3.5 - Distribution, in percentage, of greenhouse holdings per class of area, in the Algarve region.

year	greenhouse area (ha) ≤1	>1-5	>5	>25*	source
1978	91	8.5	0.5		Assunção & Costa, 1979
1984	10.4	53.4	36.2	5.5	Zettelmeyer & Henriques, 1986

*- this value is included in the previous column.

It is also worth mentioning that the great increase in greenhouse area took place under economic conditions in the country in which structural changes favoured either small, even part-time, farms with less than 4 ha or very big farms. Furthermore investment was encouraged in real rather than financial assets by a negative real interest rate on time-deposits (Monke *et al.*, 1986).

Most growers are owners of the land and many of them already grew field vegetables (Assunção & Costa, 1979; Monteiro, *in press*). The majority of the holdings are run on a family basis (Zettelmeyer & Henriques, 1986) but large holdings (bigger than 5 ha) are mainly run as a company (Assunção & Costa, 1979) and employ temporary workers, 80% of them being women, and sometimes a small permanent staff (Zettelmeyer & Henriques, 1986). In the Algarve the casual workers used to be mainly from the Alentejo districts, but nowadays they can come from more northern districts, while in the West region they are mainly local residents. As a result, in the Algarve, companies must have basic accommodation for their temporary workers.

Greenhouses are generally wooden structures made by the

growers themselves, saddle-roof shaped, 8-9 m wide and 50--70 m long if built as a single-span, covered with plastic (in the early days of the industry the plastic used was the standard polythene, which was replaced later by long-life polythene and by "thermal" polythene, the latter with a thickness of 0.2 mm), at very low cost, varying from 2.5 US$ to 4 US$ per m^2 (Monteiro, 1983; Monteiro *et al.*, 1988). To reduce the amount of plastic used in a considerable way, half of the growers in the Algarve region prefer to build multiple-span greenhouses, which cover 64.4% of the greenhouse area (Monteiro, 1983; Zettelmeyer & Henriques, 1986), and in this case the length of the structure was reduced to 25-30 m in recently built greenhouses.

Some attempts have been made to use glasshouse structures applying high technological production systems imported from northern Europe but these structures are not common. They are almost always linked with foreign investment projects and some of them performed very badly under local conditions.

Normally greenhouses do not have heating systems and there is very poor environmental control inside (Monteiro *et al.*, 1988). Ventilation is particularly important to reduce day temperature and excessive moisture, to reduce night condensation and consequently to reduce the risk of diseases (Monteiro, 1983). This is achieved through lateral windows, open during the day time.

Other important constraints on this "mild winter" cropping system are low temperature at night and low light during the winter period (Monteiro & Portas, 1986). On average, there are heavy frosts every five years in the Algarve region (Cunha, 1982) and the annual number of days with light frosts is less than ten (Monteiro, 1983). The use of sprinkler systems as a preventive measure against frost damage is very popular (Monteiro *et al.*, 1988). In the West the winter temperatures are slightly lower than in the Algarve but the risk of light frost is relatively small owing to the proximity of the sea.

In the West region soils are mainly light or sandy but in the Algarve they are mainly heavy soils, sometimes with drainage problems.

Growers normally apply high levels of manure and too much nitrogen (Barradas *et al.*, 1979). Zettelmeyer & Henriques (1986) reported some nitrogen applications in tomato crops in the Algarve: for a yield level of 100 t ha^{-1}, five times bigger than the amount the plants need for that yield level was applied, and on average growers apply twice the amount of nitrogen required for the plant. On the other hand, potassium fertilisation is, on average, less than the amount required for the plant.

In the Algarve region many growers have problems with salinity in water and soils (Barradas *et al.*, 1979), which is particularly bad because 98% of the growers in the Algarve get water from their own wells (Zettelmeyer &

Henriques, 1986). Trickle irrigation is the most used system, generally carrying a nutrient solution (Fonseca *et al.*, 1986). According to Zettelmeyer & Henriques (1986), in the Algarve region, 69% of the growers use perforated hoses, 18% still use furrow irrigation, 12% prefer drip irrigation and 1% use sprinkler irrigation.

The majority of the production from greenhouse crops used to be for internal consumption and only a small share was exported, less than 2% of *Solanaceae* production and some green beans (Henriques, 1986; Monteiro *et al.*, 1988; Monteiro & Portas, 1986). However, in the last 3-4 years many growers, mainly in the West region, have been able to export tomato and green beans successfully in considerable amounts to other European countries, particularly to the Netherlands.

3.3 - IMPORTANT CROPS AND THEIR CROPPING CYCLES

The most important vegetable crops are tomato, melon, green beans, lettuce, sweet pepper and cucumber. Nevertheless they do not have the same importance in the Algarve and in the West (Table 3.6). Tomato has been, and still is, the most important vegetable in protected horticulture, but melons and strawberries have become very important in the Algarve, while cucumbers and sweet peppers lost importance. In the West green beans and lettuce are also important crops.

Table 3.6 - Estimated area of the main greenhouse vegetable crops in Portugal as a percentage of total greenhouse vegetable area.

Region	year	tomato	melon	green beans	lettuce	sweet pepper	cucumber	others*	source
	1972	62.1	4.3	7.7	-	13.9	11.9	0.1	Vargues, 1979
A	1973	63.9	8.3	2.6		10.9	13.1	1.2	Barradas *et al.*, 1979
L	1974	54.4	11.2	5.5	0.2	12.2	12.7	3.8	Vargues, 1979
G	1975	68.4	3.6	4.5		9.5	13.6	0.4	Barradas *et al.*, 1979
A	1976	65.5	3.3	3.7	-	11	14.7	1.8	Vargues, 1979
R	1977	71.0	5.0	5.9	-	8.8	6.5	2.8	Barradas *et al.*, 1979
V	1978	66.4	6.5	5.3	0.1	11.3	7.3	3.1	Vargues, 1979
E	1984	44.7	30.3	11.6	2.6	5.7	3.7	1.4	Zettelmeyer & Henriques, 1986
	1986	40	26.6	10.4	2.7	5.2	3.5	11.6**	Fonseca *et al.*, 1986
W									
E	1985	70	-	-	-	-	-	30	Marreiros *et al.*, 1986
S	1986	60	-	13.3	6.7	-	-	20	Fonseca *et al.*, 1986
T									

*-this value may include crops mentioned in other columns.
**-Strawberries, alone, represent 10.4%.

In ornamental production, carnations are the most important crop (58% of the ornamental protected area) followed by roses (13% of the ornamental protected area). Several other cut flowers, including gladiolus and chrysanthemum, bedding plants and pot plants are produced in the remaining area (Lança, 1985) (Table 3.7).

CROPPING CYCLES:

Tomato in the Algarve is produced mainly during the winter period (50% of the area), the seedlings being planted during October-November and harvested from February to June. However, 25% of the area is occupied with an

Table 3.7 - Estimated percentage values of the area of greenhouse ornamental crops in Portugal in 1985 (Lança, 1985), compared with the situation in 1975 (Louro *et al.*, 1975).

\ year crop\	1975 %	1985 %
carnations	74	58
roses	10	13
gladiolus	2.4	4
other cut flowers		7
bedding plants	8.6	
pot plants		15
propagative material (carnation & chrysanthemum)	5	3

autumn cycle, planted at the end of August or early September and harvested from November until February while in the other 25% of the area the growers adopt a spring cycle planting in January and harvesting from April-May to the end of July (Zettelmeyer & Henriques, 1986) (Fig. 3.2).

Nowadays the most important cultivars are Carmello, Ultra-boy and Dombito but some years ago the most popular cultivar was Monte Carlo. Plant density generally varies from 2.5 to 3.5 plants m^{-2}. Auxin spraying of tomato flowers is very popular amongst growers (Marreiros *et al.*, 1986). Growers use plastic mulching on 33% of the tomato area, mainly black plastic (Zettelmeyer & Henriques, 1986). Henriques (1986) refers to production of 84 t ha^{-1} on average.

In the West, with its cooler summers, there are only two cropping cycles: the autumn one (60% of the area) is

planted early in August and the harvest runs from mid--October till late January; the spring cycle (40% of the area) is planted in February and the harvest is from April to July (Marreiros *et al.*, 1986) (Fig. 3.3). The most important cultivars are Dombito and Dombello (beefsteak type cultivars) (Marreiros *et al.*,1986).

Melon is mainly grown in the Algarve in the spring period and is always produced as a climbing crop inside greenhouses. Planting is generally in February and harvest begins at the end of April; normally it continues until June or July (Fonseca *et al.*, 1986) (Fig. 3.2). In the Algarve 74% of the melon area is covered with plastic mulching, mainly black plastic (Zettelmeyer & Henriques, 1986). These authors refer to production of 56 t ha^{-1} on average and Monteiro (*in press*) indicated the expected yield level was between 50 and 70 t ha^{-1}. The most important cultivars are Galia, Harvest King and Macdimon (Fonseca *et al.*, 1986), with planting densities between 1.5-2.3 plants m^{-2} (Zettelmeyer & Henriques, 1986).

Green beans are grown in the autumn, winter and spring and, as a result, the greenhouse production begins in November and finishes in June (Figs. 3.2 and 3.3). This crop is normally direct sown, with plant densities ranging from 4.6 to 9-15 m^{-2}, if sown in a double line (Fonseca *et al.*, 1986; Zettelmeyer & Henriques, 1986).

In the Algarve the most important cultivars are Selka and Kwintus, 21% of the area of the crop is covered with

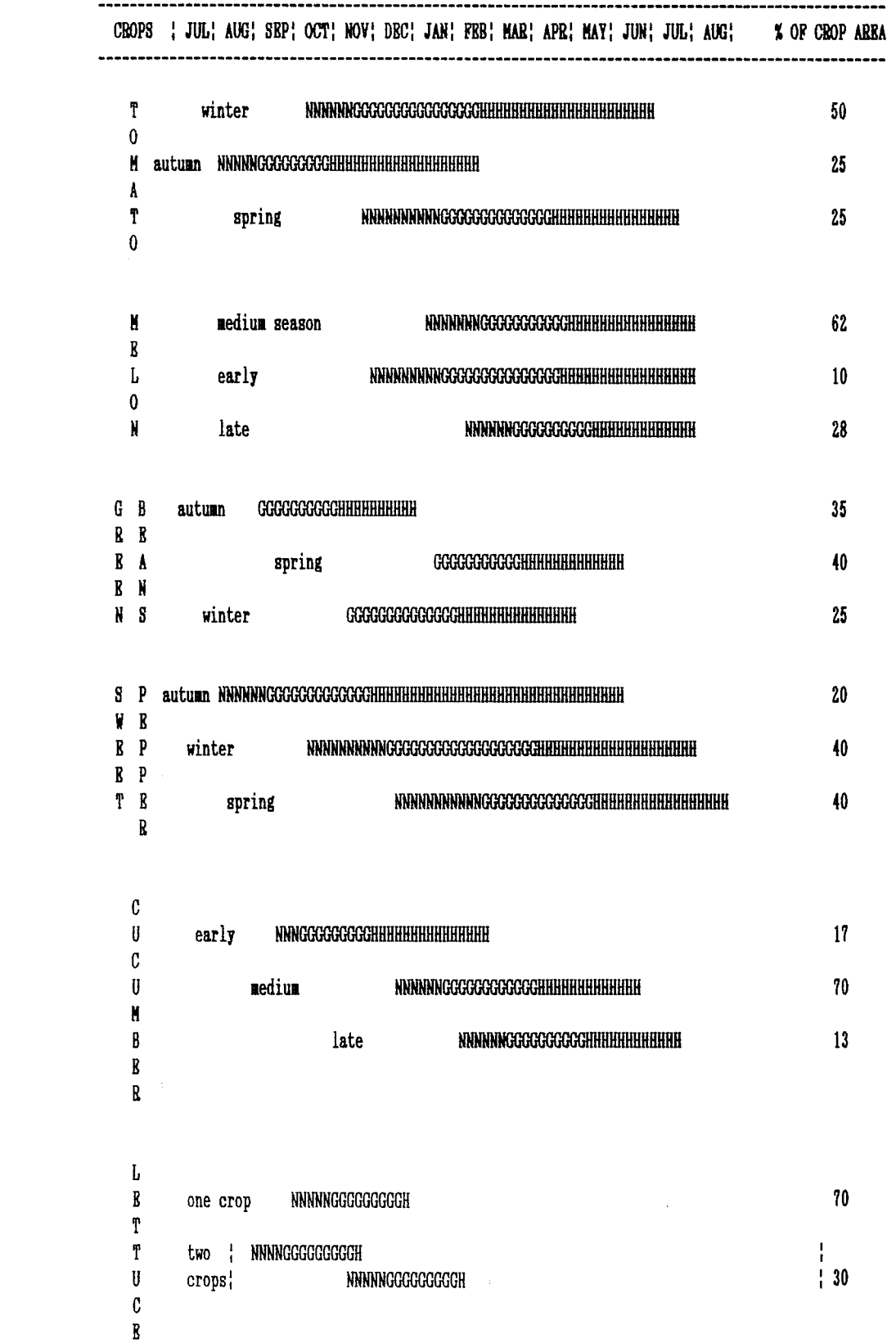


Fig. 3.2 - Cropping-cycles of the main vegetable crops in the Algarve.
(N- nursery period; G- vegetative growing period; H- harvest period)

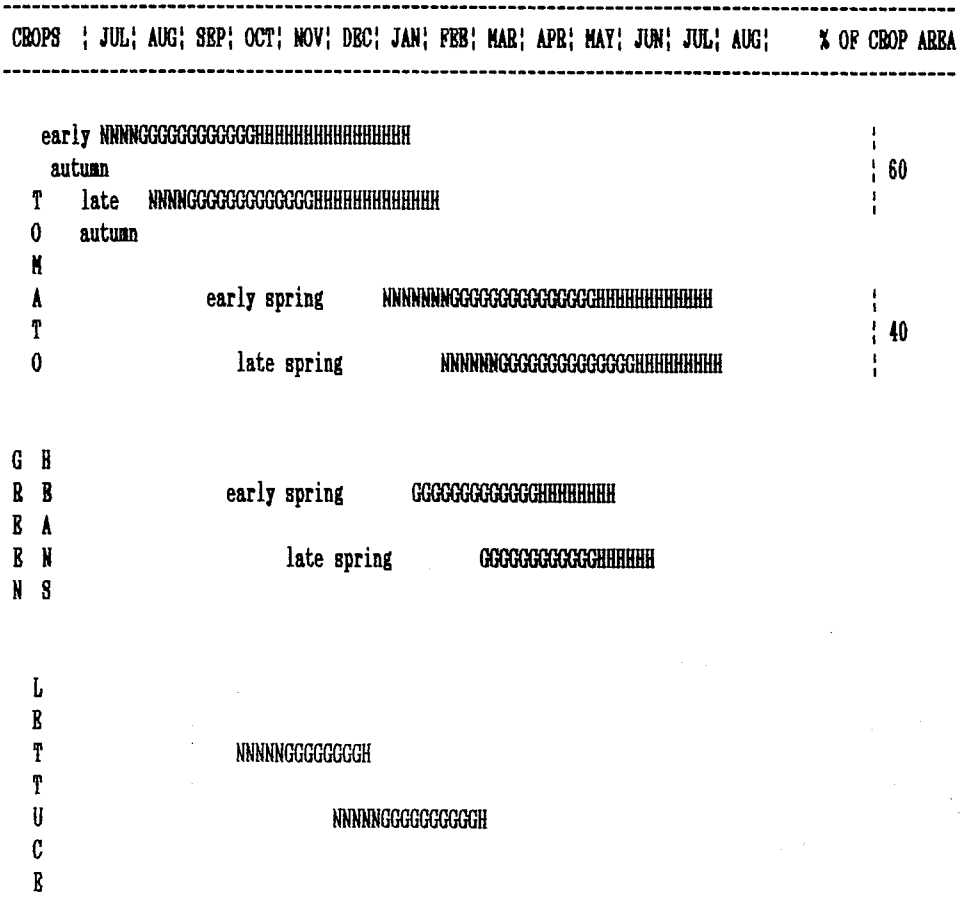


Fig. 3.3 - Cropping-cycles of the main vegetable crops in the West.
[N- nursery period; G- vegetative growing period; H- harvest period]

plastic mulching (Zettelmeyer & Henriques, 1986) and the average yield is 30 t ha^{-1} (Fonseca *et al.*, 1986). Henriques (1986) reported 22 t ha^{-1} as the average yield from the Algarve.

Lettuce is grown in greenhouses from September or October until January-February (Figs. 3.2 and 3.3). Planting density is, on average, 13 plants m^{-2} (Zettelmeyer & Henriques, 1986). This crop presents a short growing period and sometimes it is possible to get two consecutive

crops in the same greenhouse between an autumn tomato crop and a spring tomato, green bean or melon crop. The butterhead cultivars, like Selma, are the most important (Monteiro, *in press*), but the cultivar Iceberg represents 19% of the area of the crop in the Algarve (Zettelmeyer & Henriques, 1986). The average yield is 60 t ha^{-1} for the Algarve (Zettelmeyer & Henriques, 1986).

Sweet pepper is transplanted in the Algarve from September to February (Fig. 3.2), early dates being preferred for economic reasons (higher yield and earliness) (Marreiros *et al.*, 1986) and ecological reasons (high temperature requirements of the crop, especially early in development) (Monteiro & Portas, 1986). In the Algarve plant density is, on average, 2.6 plants m^{-2} and half the area of the crop is covered with black plastic mulching (Zettelmeyer & Henriques, 1986). Harvest begins in November-December for early planted crops, and can go until August (Marreiros *et al.*, 1986). The most popular cultivar is Lamuyo (Marreiros *et al.*, 1986) and, on average, yield reaches 56 t ha^{-1} (Zettelmeyer & Henriques, 1986).

Finally, cucumber is mainly transplanted from the end of December until February (70% of the area of the crop) and is harvested from March-April until July (Fig. 3.2) (Zettelmeyer & Henriques, 1986). The most popular cultivars are Victory and Triumph because the internal market prefers small fruits (15-25 cm) with round extremities (Costa, 1984). Plant density is normally 3 plants m^{-2}, 49% of the area of the crop is covered with

plastic mulching and yield is 96 t ha^{-1}, on average, in the Algarve (Zettelmeyer & Henriques, 1986).

3.4 - PEST PROBLEMS AND CROP PROTECTION MEASURES

Growers face several pest problems and they almost exclusively use chemical control. As a result of poor environmental control air-borne diseases are quite important and growers are forced to employ very intensive spraying schemes. Due to a very intensive crop sequence and lack of a convenient rotation soil-borne diseases are growing in importance, creating extra difficulties to the growers.

Guimarães & Sousa (*in press*) recently presented a list containing the harmful organisms recorded in Portugal attacking greenhouse crops of tomato, green beans, carnations, roses, chrysanthemums and gladiolus. Precise data about the different pesticides applied per crop was only available for the Algarve region owing to the survey work done in this region in 1984-85 and reported by Zettelmeyer & Henriques (1986).

On <u>tomato</u> (Table 3.8) the most important air-borne diseases are grey mould (*Botrytis cinerea*) and late blight (*Phytophthora infestans*) and some growers use as many as 25 sprays, one every five days (Fernandes, 1979). However, Guimarães & Sousa (*in press*) indicated *Fusarium* wilt disease as the major pest problem on this crop requiring

technical advice from the crop protection services of the Ministry of Agriculture. Several other diseases occasionally develop, such as powdery mildew, early blight and septoria leaf spot (Barrote *et al.*, 1977; Caupers, 1980; Kakoobhai, 1984). Concerning soil-borne diseases, corky root rot (*Pyrenochaeta lycopersici*) and wilt diseases (*Fusarium oxysporum*, *Verticillium* spp.) are becoming important problems in some places.

Root-knot nematodes (*Meloidogyne* spp.) are a major constraint to the crop in many areas of the country (Caupers, 1980; Costa, 1984). Since *Meloidogyne* species have a great morphological and physiological variability, the identification of the root-knot nematodes attacking crops is sometimes uncertain (Abrantes *et al.*, 1985). However, the four major root-knot nematode species affecting vegetables (*Meloidogyne hapla*, *M. arenaria*, *M. incognita* and *M. javanica*) are present in the country and have been identified from a wide range of crops (Table 3.9).

Viruses are sometimes reported as very important (Costa, 1984) and Tobacco Mosaic Virus (TMV) is the most important virus in tomato in Portuguese greenhouses (Borges & Sequeira, 1986).

Bacterial diseases are occasionally reported in some places ((*Clavibacter michiganense* subsp. *michiganense*) (Guimarães & Sousa, *in press*), (*Erwinia carotovora* subsp. *carotovora*) (Costa, 1980), (*Pseudomonas syringae* pv. *tomato*)(Oliveira &

Marta, 1986), (*P. corrugata*)(Marta, 1985)), but antibiotics are not approved for agricultural use in the country.

Of the insect pests, aphids and whitefly demand continuous care (Guimarães & Sousa, *in press*). Whitefly has become an important pest problem in the Algarve in recent years; in 1977 whitefly was not yet reported as a tomato pest in this region (Barrote *et al.*, 1977). In the West region growers do not yet consider this pest as important as it is in the Algarve.

Caterpillars, mainly from the family *Noctuidae* (subfamilies *Plusiinae, Noctuinae, Heliothinae* and *Amphipyrinae* (following the classification of Holloway *et al.*, 1987)) (Guimarães & Sousa, *in press*), and spider mites are frequent pests and leafminers are occasional pests. *Liriomyza bryoniae* has been reported as the only species of leafminer attacking tomato in the country (Guimarães & Sousa, *in press*); however, the recent identification of *L. trifolii* in Gypsophila plants imported into the U.K. from Portugal (Seymour *et al.*, 1986) could mean that this pattern will change in the near future.

Weed control is also important for the crop, including the area outside greenhouses, and is mainly done by hand/hoeing (Guerreiro, 1979; Zettelmeyer & Henriques, 1986). Some growers use black plastic mulch to control weeds and increase soil temperature (Marreiros *et al.*, 1986) and, in the Algarve, a small number use herbicides (applied by

2.5% of the growers who have tomato), mainly metribuzin and dinitramine (Zettelmeyer & Henriques, 1986). As tomato cultivars vary in the susceptibility they have to the a.i. metribuzin (Gawronski, 1983) and growers like to plant the most recent cultivars, they must use herbicides carefully.

To control soil diseases, nematodes and occasional insect pests, some growers in the Algarve region apply methyl bromide (5% of the growers who have tomato) and dazomet (3.5% of the growers who have tomato) (Zettelmeyer & Henriques, 1986), sometimes in a alternate scheme (Caupers,1980). Both of these chemicals also control weed seeds.

Against air-borne diseases dithiocarbamates (mancozeb and propineb), dicarboximides (vinclozolin, iprodione, procymidone), benzimidazole (benomyl) and triazole (triadimefon) have been the most used fungicides, while new systemic fungicides against downy mildews (metalaxyl, cymoxanil) are reported to be used only by a small number of growers according to data collected by Zettelmeyer & Henriques (1986) in the Algarve region.

Pyrethroids (deltamethrin, permethrin), organo-phosphates (acephate, methamidophos, parathion and oxydemeton-methyl) and carbamates (methomyl, pirimicarb) are reported as the most used insecticides and dicofol in mixture with tetradifon is the most popular acaricide in the region (Zettelmeyer & Henriques, 1986).

On melon, (Table 3.8), powdery mildew and *Fusarium* wilt have been reported as major problems (Fernandes, 1979; Caupers, 1980; Costa, 1984; Monteiro, *in press*). Apart from *Fusarium* wilt, Guimarães & Sousa (*in press*) indicated also attacks of *Rhizoctonia* foot rot and *Verticillium* wilt. Root-knot nematodes (*Meloidogyne* spp.) are another important constraint on the crop in many places (Table 3.9) (Barrote *et al.*, 1977; Caupers, 1980). Grey mould is also a frequent disease (Caupers, 1980).

Spider mites, aphids and whiteflies are important pests of the crop (Barrote *et al.*, 1977; Caupers, 1980) and thrips are, in some places, occasional pests (Monteiro, *pers. comm.*).

Fenamiphos, methyl bromide and dazomet are the pesticides applied to control soil pests of this crop in the Algarve. Powdery mildew is mainly controlled with triadimefon, fenarimol and quinomethionate; against grey mould growers apply benomyl, iprodione and vinclozolin. Dithiocarbamate fungicides (mancozeb and propineb) are also widely used in preventive spray schemes.

Pyrethroids (deltamethrin, permethrin), organo-phosphates (acephate, methamidophos, oxydemeton-methyl, trichlorfon, parathion) and carbamates (pirimicarb, methomyl) are the most common insecticides and dicofol in mixture with tetradifon is the most popular acaricide according to data collected for the Algarve region (Zettelmeyer & Henriques, 1986).

Table 3.8 - Damage matrix showing the plant components which are affected by pests.

[Each * indicates an existing damage effect; each (*) indicates a possible damage effect, not recorded in Portugal]
[R - root ; S - stem ; L - leaves ; Fl - flowers ; Fr - fruits]

PESTS \ CROPS	tomato				melon				green beans			lettuce			sweet pepper				cucumber				carnation				rose			
	R	S	L	Fr	R	S	L	Fr	R	S	L	R	S	L	R	S	L	Fr	R	S	L	Fr	R	S	L	Fl	R	S	L	Fl
Phytophthora infestans (Mont.) de Bary (late blight)	*	*	*																											
Peronospora sparsa Berk. (downy mildew)																												*	*	
Bremia lactucae Regel (downy mildew)												*																		
Uromyces appendiculatus (Pers.) Unger (rust)									*	*																				
U. dianthi (Pers.) Niessl. (rust)																							*	*						
Phragmidium tuberculatum Müll. (rust)																												*	*	*
Leveillula taurica (Lév.) Arnaud (powdery mildew)	*				(*)										*				(*)											
Sphaerotheca fuliginea (Schlecht. ex Fr.) Poll. (powdery mildew)					*	*													*	*										
S. pannosa (Wallr.) Lév. (powdery mildew)																												*	*	*
Erysiphe cichoracearum DC. ex Mérat (powdery mildew)					*	*						(*)							*	*										
E. polyphaga Hammarl. (powdery mildew)					(*	*)													*	*										
Marssonina rosae (Lib.) Died. (blackspot)																												*		
Coniothyrium fuckelli Sacc. (canker)																												*		
Sclerotinia sclerotiorum (Lib.) de Bary (sclerotinia disease)	*	*			*	*	*		*	*		*	*						(*	*	*)		*							

Table 3.8 - (cont.)

PESTS \ CROPS	tomato				melon				green beans				lettuce			sweet pepper				cucumber				carnation				rose			
	R	S	L	Fr	R	S	L	Fr	R	S	L	Fr	R	S	L	R	S	L	Fr	R	S	L	Fr	R	S	L	Fl	R	S	L	Fl
Colletotrichum lindemuthianum (Sacc. & Magn.) Br. & Cav. (anthracnose)									x	x	x																			
Alternaria solani Sorauer (early blight)	x	x	x													(x	x	x)												
Alternaria dianthi Stev. & Hall (alternaria blight)																									x	x	x			
Septoria lycopersici Speg. (septoria leaf spot)		x	x																											
Botrytis cinerea Pers. (grey mould)	x	x	x		x	x	x		x	x	x		x	x		x	x			x	x	x		x		x	(x	x	x)	
Fusarium oxysporum Schlecht. f. sp. *lycopersici* (Sacc.) Snyd. & Hans. (wilt disease)	x	x																												
f. sp. *melonis* (Leach & Currence) Snyd. & Hans. (fusarium wilt)					x	x																								
f. sp. *dianthi* (Prill. & Del.) Snyd. & Hans. (fusarium wilt)																									x	x				
Fusarium spp. (root rot)									x	x																				
Pyrenochaeta lycopersici Schneider & Gerlach (corky root rot)	x				(x)																									
Verticillium alboatrum Reinke & Berth. (verticillium wilt)	x				x															(x)								(x)		
Verticillium dahliae Kleb. (verticillium wilt)	x				x															(x)								(x)		
Rhizoctonia solani Kühn (rhizoctonia foot rot)	x	x			x	x			(x)				(x	x)		(x	x)			(x)				x						

Table 3.8 - (cont.)

PESTS \ CROPS	tomato R	tomato S	tomato L	tomato Fr	melon R	melon S	melon L	melon Fr	green beans R	green beans S	green beans L	green beans Fr	lettuce R	lettuce S	lettuce L	sweet pepper R	sweet pepper S	sweet pepper L	sweet pepper Fr	cucumber R	cucumber S	cucumber L	cucumber Fr	carnation R	carnation S	carnation L	carnation Fl	rose R	rose S	rose L	rose Fl
Clavibacter michiganense subsp. *michiganense* (Smith) Davies *et al.* (bacterial canker)	x	x	x																												
Erwinia carotovora subsp. *carotovora* (Jones) Bergey *et al.* (bacterial soft rot)	x		x																												
Pseudomonas syringae pv. *tomato* (Okabe) Young *et al.* (bacterial spot)	x	x	x																												
P. corrugata Roberts & Scarlett (pith necrosis)	x	x																													
P. syringae pv. *phaseolicola* (Burk.) Young *et al.* (halo blight)										x	x																				
Tobacco Mosaic Virus		x	x														x	x													
Potato Virus X		x	x														x	x													
Potato Virus Y		x	x														x	x													
Cucumber Mosaic Virus		x	x		x	x								(x)			x	x		x	x										
Tomato Bushy Stunt Virus		x	x														(x	x)													
Bean Common Mosaic Virus										x																					
Bean Yellow Mosaic Virus										x																					
Rose Mosaic Virus																														x	
Carnation Mottle Virus																									x	x	x				
Carnation Vein Mottle V.																										x	x				
Tomato " Mal-azul" (mycoplasma)		x	x	x																											

Table 3.8 - (cont.)

PESTS \ CROPS	tomato				melon				green beans			lettuce			sweet pepper				cucumber				carnation				rose			
	R	S	L	Fr	R	S	L	Fr	R	S	L	R	S	L	R	S	L	Fr	R	S	L	Fr	R	S	L	Fl	R	S	L	Fl
Meloidogyne spp. (root-knot nematodes)	x				x				x			x			x				x				x				(x)			
Ditylenchus dipsaci (Kühn) Filip.	x				x				x																					
Thrips tabaci Lindeman (onion thrips)	x				(x)				x										x				x				x	x		
Heliothrips haemorrhoidalis (Bouché) (glasshouse thrips)																											x	x		
Haplothrips cottei Vuillet																							x	x						
Thrips fuscipennis Haliday (rose thrips)	x	x																	(x	x)							x	x		
Taeniothrips atratus Haliday (carnation thrips)																								x						
Trialeurodes vaporariorum (Westwood) (glasshouse whitefly)	x	x			x	x			x						x	x			x				x	x			x			
Bemisia tabaci (Genn.) (cotton whitefly)	(x	x)			(x)				(x)						(x)				(x)											
Myzus persicae (Sulzer) (peach-potato aphid)	x				(x)				x			(x)			x				(x)				x	x			x			
Macrosiphum euphorbiae (Thomas) (potato aphid)	x				(x)				x			(x)			(x)				(x)								x			
M. rosae (L.) (rose aphid)																											x			
Aphidura pujoli Gomez-Menor																							x							

Table 3.8 - (cont.)

PESTS \ CROPS	tomato				melon			green beans			lettuce			sweet pepper			cucumber			carnation				rose			
	R	S	L	Fr	R	S	L	Fr	R	S	L	Fr	R	S	L	Fr	R	S	L	Fr	R	S	L	Fl	R	S	L	Fl
Aphis fabae Scopoly (black bean aphid)	x							x																	x			
A. gossypii Glover (melon aphid)					(x)									(x)			x								x			
Aulacorthum solani (Kaltenbach) (Glasshouse potato aphid)	x													x											x			
Rhodobium porosum Sanderson																									x			
Planococcus citri (Risso) (citrus mealybug)																									x			
Pseudococcus longispinus Targ. (long tailed mealybug)																									x			
Helicoverpa armigera (Hübner) (old world bollworm)		x												(x)							x	x		x	x		
Agrotis segetum (Denis & Schiffermüller) (turnip moth)	x						x														x		x				
Spodoptera littoralis (Boisduval) (mediterranean climbing cutworm)	x																x										
S. exigua (Hübner) (beet armyworm)	x							x																				
Mamestra brassicae (L.) (cabbage moth)	(x)							(x)			(x)			(x)											x			
Autographa gamma (L.) (silver Y moth)	x							(x)			(x)			(x)							x				x			
Chrysodeixis chalcites (Esper) (golden twin spot moth)	x																				x				x			

Table 3.8 - (cont.)

PESTS \ CROPS	tomato			melon			green beans			lettuce			sweet pepper			cucumber			carnation			rose		
	R	S	L	Fr	R	S	L	Fr	R	S	L	R	S	L	Fr	R	S	L	Fr	R	S	L	Fl	R	S	L	Fl
Cacoecimorpha pronubana (Hübner) (carnation tortrix moth)																				x	x		(x | x)	
Liriomyza brioniae (Kaltenbach) (tomato leaf-miner)	x			(x)							(x)							(x)							
L. trifolii (Burgess) (american serpentine leaf miner)	(x)			(x)			(x)				(x)			(x)				(x)							
Tetranychus urticae Koch (two-spotted spider mite)	x			x			x							x				x		x			x		
T. ludeni L.	x			x			x													x			x		
T. atlanticus McGr.				(x)			x											x					x		
Brevipalpus californicus Banks																		x					x		
B. obovatus Don.																		x					x		
Aculops lycopersici (Massee) (tomato russet mite)	x	x											x	x											

Aphids, spider mites, grey mould, *Fusarium* root rot, *Sclerotinia* disease and whitefly are the key pests of <u>green beans</u> (Candeias, 1979; Monteiro, *in press*; Guimarães & Sousa, *in press*; Semedo, *pers. comm.*).

Anthracnose, halo blight and rust are occasional diseases (Table 3.8).

A small number of growers in the Algarve apply methyl bromide, dazomet, steam or fenamiphos to control soil pests. Pyrethroids (deltamethrin mainly, but sometimes permethrin) are the most applied insecticides but organo--phosphates (acephate, oxydemeton-methyl, parathion and methamidophos) and carbamates (methomyl, pirimicarb) are also commonly sprayed. Dicofol in mixture with tetradifon is the most used acaricide. Dithiocarbamates (mancozeb and propineb) are the most common fungicides used in this crop, followed by dicarboximides (vinclozolin, iprodione and procymidone) and benzimidazole (benomyl). Triadimefon, fenarimol and pyrazophos are sometimes applied against powdery mildew (Zettelmeyer & Henriques, 1986).

Lettuce is mainly affected by *Sclerotinia* disease and grey mould but downy mildew and aphids are occasional pest problems (Table 3.8) (D.G.P.P.A., 1980; Lucas & Lopes, 1987; Semedo, *pers. comm.*). Weeds are also an important constraint on the crop and weed control is mainly done by hand, although propyzamide herbicide is also very popular.

On sweet peppers, aphids are an important pest and whitefly, spider mites, powdery mildew and grey mould are also frequent pest problems (Candeias, 1979; Caupers, 1980; D.G.P.P.A., 1980; Sequeira, 1987) (Table 3.8). Viruses are sometimes reported as very important (Costa, 1984).

Table 3.9 - Root-knot nematodes affecting vegetables in Portugal

\ Reference	Taylor *et al.*, 1982			Santos & Abrantes, 1983		
SPECIES (race) \	occurrence	regions	hosts	occurrence	regions	hosts
Meloidogyne hapla Chitwood	X	- Beira Litoral (Littoral Centre)	carrot	X	- Minho (Littoral North) - Beira litoral - Algarve (South)	carrot alfalfa maize squash
M. arenaria (Neal) Chitwood (race 2)	X	- Beira litoral - Algarve	tomato (olive tree)	X	- Beira litoral	tomato
M. incognita (Kofoid & White) Chitwood (race 2)				X	- Oeste (West) - Algarve	melon maize beans
(race 3)	X	- Algarve	(olive tree)			
(race 4)				X	- Algarve	maize
M. javanica (Treub) Chitwood	X	- Beira interior (Interior Centre)	potato	X	- Beira interior - Algarve	tomato potato beans

In the Algarve soil sterilants are not commonly used before this crop, but sometimes growers apply methyl bromide or dazomet. Growers use mainly dithiocarbamates (mancozeb and propineb), but dicarboximides (vinclozolin, iprodione, procymidone), benzimidazole (benomyl), acylalanine (metalaxyl), triazole (triadimefon), pyrimidine (fenarimol) and quinoxaline (quinomethionate) fungicides are also used to control diseases in this crop.

Pyrethroids (mainly deltamethrin), organo-phosphates (acephate, methamidophos, oxydemeton-methyl) and carbamates (pirimicarb, methomyl) are the main insecticides applied on this crop in the Algarve (Zettelmeyer & Henriques, 1986).

Weed control is also essential in sweet pepper, so growers solve this problem in the Algarve region by hand weeding, black plastic mulch, and a few of them use dinitramine (Marreiros *et al.*, 1986; Zettelmeyer & Henriques, 1986).

On cucumber, aphids, spider mites, whitefly, powdery mildew and grey mould are the common pest problems (Table 3.8).

In the Algarve growers use mainly dithiocarbamates (mancozeb and propineb), dicarboximides (vinclozolin, iprodione, procymidone), benzimidazole (benomyl), triazole (triadimefon), pyrimidine (fenarimol) and quinoxaline (quinomethionate) fungicides. The most used insecticides are pyrethroids (mainly deltamethrin), organo-phosphates (acephate, methamidophos, oxydemeton-methyl) and carbamates (pirimicarb, methomyl). Dicofol in mixture with tetradifon is the most used acaricide. A small number of growers apply methyl bromide or fenamiphos before this crop and an even smaller number of growers use herbicides (Zettelmeyer & Henriques, 1986).

On ornamentals only carnation and rose are reviewed here because they are the most important ornamental crops.

Aphids, *Fusarium* wilt and nematodes are the main problems

to the carnation crop (Lança, *pers.comm.*), but grey mould, *Rhizoctonia* stem rot and rust are widespread diseases; *Alternaria* blight, Carnation Mottle Virus, spider mites, thrips, whitefly and caterpillars can also be occasional pest problems (Bettencourt, 1985; Borges, 1985; Guimarães & Sousa, *in press*) (Table 3.8).

On rose, powdery mildew and spider mites are the most important pest problems (Lança, *pers.comm.*), but canker, blackspot, downy mildew, rust, aphids, nematodes, Prunus Necrotic Ringspot Virus, Rose Mosaic Virus, mealybugs and caterpillars are frequent pests of this crop (Bettencourt, 1985; Borges, 1985) (Table 3.8).

3.5 - DISCUSSION OF CROP PROTECTION MEASURES

The structure of the Portuguese greenhouse agroecosystem, based on the information collected from literature, can be described by its components, as presented in Table 3.10.

The output of all vegetable crops but lettuce is the fruit. As the main crops (tomato, melon, green beans and cucumber) have an indeterminate growth, plants can generally compensate for any minor indirect damage suffered in the initial phases of the development of the crop. However, the timing of production plays a central role in this agroecosystem, since prices are much higher early in the season than later, when competition with the open field crops became increasingly important.

Table 3.10 - Structure of the Portuguese greenhouse agroecosystem

INPUTS	COMPONENTS & SUB-COMPONENTS OF GREENHOUSE AGROECOSYSTEM							OUTPUT
	ENVIRONMENTAL CONDITIONS	CROPS (BOTAN.FAM.)	CULTIVARS	ARTHROPOD PESTS	PATHOGENS	WEEDS (a)	BENEFICIAL ORGANISMS(b,c,d)	
1- climatic	1- aerial		Dombito	whitefly	grey mould	*Amaranthus*	*Coccinella*	
			Dombello	caterpillars	late blight	*retroflexus*	*septempun-*	
-temp.	temp.	1- Tomato	Carmello	spider mites	powdery		*ctata*	fruit
-light	humidity		Dombo	aphids	mildew	*Chenopodium*		
-CO_2	light	(*Solanaceae*)	Ultra boy	leafminers	early	*album*	*Adalia*	
-wind	CO_2 level		Marca	russet mite	blight		*bipunctata*	
-humidity	air movement		Floritalia	...	septoria	*Chenopodium*		
			Monte Car-		leaf spot	*murale*	*Chrysopa spp*	
2- management	2.a- soil		lo, ...		corky root			
					rot	*Convolvulus*	*Encarsia*	
-manure	type-				wilt disea-	*arvensis*	*formosa*	
-fertiliser	-pH				ses			
-irrigation	-texture				root knot	*Fumaria*	*Lysiphlebus*	
-ventilation	-structure				nematodes	*agraria*	*fabarum*	
-agrochemicals	-organic				virus			
-beneficial	matter				bacterias	*Lolium*	*Aphidius*	
organisms	-electric				...	*rigidum*	*rosae*	
-solarization	conducti-							
-planting date	vity	2- Sweet	Lamuyo	aphids	powdery	*Poa annua*	*Aphidius*	
-crop density	temp.	Pepper	Hybrid	whitefly	mildew		*matricariae*	
-plant	moisture		pepper	spider mites	grey mould	*Poligonum*		fruit
management*	nutrient		Sonar	...	viruses	*aviculare*	*Diaeretiella*	
-season length	status	(*Solanaceae*)	Argo		...		*rapae*	
-crop sequence			...			*Polypogon*		
						viridis	*Phytoseiulus*	
3- market		3- Egg-	Bonica				*persimilis*	
	2.b- non soil	plant				*Portulaca*		fruit
						oleraceae	*Phytoseiulus*	
		(*Solanaceae*)					*macropilis*	
	nutrient					*Setaria*		
	solution	4- Melon	Galia	spider mites	powdery	*verticilata*	*Verticillium*	
			Harvest	aphids	mildew		*lecanii*	
		(*Cucurbi-*	King	whitefly	root rot	*Sonchus*		fruit
	inert	*taceae*)	Macdimon	thrips	root knot	*oleraceae*	*Entomophthora*	
	substrate		Galicum	...	nematodes		spp.	
			Hogan		grey mould	*Spergularia*		
			...		downy	*purpurea*	...	
					mildew			
					...	*Stellaria*		
						media		
		5- Cucumber	Victory	aphids	powdery			
			Triumph	whitefly	mildew	...		fruit
		(*Cucurbi-*	Royal	spider mites	grey mould			
		taceae)	sluis	...	...			
			...					

Table 3.10 - (cont.)

INPUTS	COMPONENTS & SUB-COMPONENTS OF GREENHOUSE AGROECOSYSTEM							OUTPUT
	ENVIRONMENTAL CONDITIONS	CROPS (BOTAN.FAM.)	CULTIVARS	ARTHROPOD PESTS	PATHOGENS	WEEDS	BENEFICIAL ORGANISMS	
1- climatic	1- aerial	6- Water--melon (*Cucurbitaceae*)	Sugar--baby	spider mites		...	...	fruit
-temp.	temp.			...				
-light	humidity							
-CO_2	light							
-wind	CO_2 level		Dos mercados	aphids	*sclerotinia*			
-humidity	air movement	7- Lettuce	Iceberg	...	grey mould			leaves
2- management	2.a- soil	(*Compositae*)	Selma		...			(entire plant)
			Batavia					
-manure	type-		Lour					
-fertiliser	-pH		Edgar					
-irrigation	-texture		Repolhuda					
-ventilation	-structure		...					
-agrochemicals	-organic							
-beneficial organisms	matter -electric	8- Green beans	Selka	aphids	grey mould			
-solarization	conducti-		Kwintus	spider mites	anthracnose			
-planting date	vity		Meru RS	whitefly	rust			
-crop density	temp.	(*Leguminosae*)	Raiado		powdery			
-plant	moisture		Maravilha	...	mildew			
management*	nutrient		...		halo blight			fruit
-season length	status				...			
-crop sequence			Tufts					
		9-straw-	Sequoia					
3- market		berries	Tioga					
	2.b- non soil		Teutz					fruit
		(*Rosaceae*)	Douglas					
			...					
	nutrient solution							
			Le reve	aphids	fusarium			
		a- Carnation	William	spider mites	wilt			stem with
	inert		Sim	thrips	nematodes			flower(s)
	substrate		Barlo	whitefly	grey mould			(some leaves)
		(*Caryophilaceae*)	Tangerine	caterpillars	rhizoctonia			
			Pink Alec	...	stem rot			
			Alec		rust			
			Sparkes		alternaria			
			...		blight			
					virus			
					...			
			"Hybrid	spider mites	powdery			branch with
		b- Rose	tea" type	aphids	mildew			flower(s)
			(Sonia)	mealybugs	canker			(some leaves)
		(*Rosaceae*)		caterpillars	blackspot			

Table 3.10 - (cont.)

INPUTS	COMPONENTS & SUB-COMPONENTS OF GREENHOUSE AGROECOSYSTEM							OUTPUT
	ENVIRONMENTAL CONDITIONS	CROPS (BOTAN.FAM.)	CULTIVARS	ARTHROPOD PESTS	PATHOGENS	WEEDS	BENEFICIAL ORGANISMS	
1- climatic	1- aerial	b- Rose		...	downy mildew	...	...	
-temp.	temp.	(cont.)			rust			branch with flower(s)
-light	humidity				nematodes			(some leaves)
-CO_2	light				virus			
-wind	CO_2 level				...			
-humidity	air movement							
		c- Gladio-lus		aphids	*Botrytis*			
2- management	2.a- soil			caterpillars	rust			stem with flower(s)
				thrips	*Fusarium*			
-manure	type-	(*Iridaceae*)		spider mites	virus			
-fertiliser	-pH							
-irrigation	-texture		a wide	spider mites				
-ventilation	-structure	d- Bedding	range of	mealybugs				entire
-agrochemicals	-organic	Plants	species	...				plant,
-beneficial	matter		and					normally
organisms	-electric	Pot	varieties					
-solarization	conducti-	Plants	belong to					
-planting date	vity		several					
-crop density	temp.		botanical					
-plant	moisture		families					
management*	nutrient							
-season length	status							
-crop sequence								
3- market								
	2.b- non soil							
	nutrient solution							
	inert substrate							

* - plant management was already defined in Fig. 2.2.

a) Guerreiro, 1979

b) Borges, 1985

c) Candeias, 1979

d) Starý, 1976

This, along with the poor environmental control inside greenhouses, puts strong pressure on the growers to control pests during the early phase of crops, and they frequently rely on intensive scheduled spraying schemes.

By contrast, near the end of the crop the growers do not care too much about pest activity and, if pest problems are uncontrolled, they prefer to finish that crop and start a new one. Such behaviour creates pest reservoirs for the neighbouring crops and, in a broader sense, increases the pest propagules in the environment.

Disease control is a very important feature in this system, which growers try to achieve by preventive fungicide sprays, applied weekly. As a consequence, unnecessary insecticide applications can easily occur if growers use the same preventive approach for arthropod pests. Such behaviour is induced by the tremendous biotic potential of some insects and mites, which can reach high numbers in a short period of time if they are not detected and controlled when the infestation is low.

The use of large amounts of pesticides creates two problems: a) high levels of residues on the fruit (leaves in the lettuce crop), if the growers do not adhere to the harvest interval, which is difficult since harvest and vegetative growth of the crop are simultaneous; and, b) pest resistance to pesticides.

The costs of pesticides (including soil sterilants) represent, in the Algarve, 15% (green beans, cucumber) -

20% (tomato, sweet pepper, melon) of the direct costs of the crop. Insecticides and fungicides represent 10% of the direct costs in the tomato crop; 13% in the sweet pepper crop; 9% in the cucumber crop; 7.5% in the melon crop and 12% in the green beans crop (Zettelmeyer & Henriques, 1986).

In Chapter 3.2 it was stated that the growers apply too much nitrogen, an expensive fertiliser. Considering fertiliser costs represent, in the Algarve, 20% of the direct costs in the tomato crop; 23% in the sweet pepper and cucumber crops; 17% in the melon crop and 32% in the green bean crop (Zettelmeyer & Henriques, 1986), and the unprofitable way growers are using such an important production factor, it is hard to believe that growers will try to reduce the amounts of pesticides applied just to lower the direct costs.

However, labour costs (including running costs for machinery) are higher than direct costs for all crops in the Algarve. Pesticide application costs represent, on average, 19% of the labour costs in all crops, from 6% on green bean to 34% on sweet pepper (Zettelmeyer & Henriques, 1986). The majority of treatments are applied with knapsack sprayers at high volume, which partially explains such high costs. The use of large amounts of nitrogen, particularly when potassium is not supplied to the plant in sufficient quantities, as in the Algarve, increases the plant susceptibility to arthropods and diseases, and forces the grower to apply even more

pesticides.

The growers would need to face residue problems (if they try to export), the occurrence of serious resistance problems, or dramatic increases in labour costs to feel it necessary to reduce the amount of pesticides applied.

Beneficial organisms, like the pests, can immigrate to the greenhouse but, in general, their activity is not important since the pressure from broad spectrum pesticides is very high and they are most active late in the season, when the crop is almost finished.

Weeds can pose problems either inside the greenhouse, through competition with the crops, or outside the greenhouse as pest reservoirs, when they grow close to the greenhouse structure.

The key pests reported for the different crops are indicated in Tables 3.8, 3.9 and 3.10. However, more prospective work is still necessary (Borges, 1985), concerning both pests and beneficial organisms, in order to obtain information about the population dynamics of the pests, seasonal changes and what factors are responsible for them.

Another important general point is to understand why the actual problems remain problems and how to solve them, or at least to improve the actual control methods. What cultural practices must the grower change or improve to reduce the pest problems? How does he deal with resistance

problem?

As stated before in Chapter 2, the different inputs exert a strong effect on the components of the system, in general, and particularly on the pests. Does the grower consider his knowledge of the system good enough or does he need more information? Where and how can he obtain information? Is the grower happy with the results he obtain? Does he feel the necessity of new solutions for difficult problems he deals with?

For these and other reasons it is also very important to know the general pattern of behaviour and attitudes as well as the decision-making process of the growers to understand the management options they take.

4 — REVIEW OF DECISION-MAKING IN CROP PROTECTION

4.1 - INTRODUCTION

Decision-making processes, either in general or specifically related to agriculture, have been deeply studied during the last thirty years or so and decision--making theories have been formulated and developed using a wide range of scientific approaches, varying from statistical and economical points of view (Berger, 1980; Halter & Dean, 1971) to anthropological points of view (Barlett, 1984).

From the decision-maker's point of view decisions can be made individually or by groups (Luce & Raiffa, 1967). In agriculture decisions concerning crops and pest control practices are usually made at the individual level unless they are under special regulations, imposed by national economic policies, where individual conflicts of interest are solved by law or any governmental decision. Concerning crop protection the individual decision-maker can either be the farmer or his contractor, if the farmer produces by contract to other economic agents (e.g. cooperative, wholesaler) under very precise contract clauses.

Based on the existing knowledge about the occurrence of possible outcomes resulting from a decision, Luce & Raiffa (1967) considered three types of decisions:

- *decisions under certainty*, when a particular outcome

results always from an action;

- *decisions under risk*, when a particular action results in one of several possible outcomes, with a known probability associated;
- *decisions under uncertainty*, when a particular action results in one of several possible outcomes, with an unknown or meaningless probability associated.

The uncertainty linked with factors like pest attacks and other natural hazards (either in frequency and intensity), availability of new technology (new pest control techniques, pesticides, or other production factors) and prices, made agricultural decisions in general, and pest control decisions in particular, proper decisions under uncertainty (Halter & Dean, 1971; Mumford, 1978).

Every decision problem has several decision components (Chernoff & Moses, 1959; Halter & Dean, 1971):

- *the available actions*, highlighting all the alternative actions for the problem;
- *the states of nature*, which can occur;
- *the consequences of the actions*, assessed for each combination of action and state of nature, either in terms of loss or utility (the outcome matrix);
- *an experiment*, to obtain information about the state of nature and assess their probabilities of occurrence in relation with particular observations;
- *the available strategies*, indicating which action should be taken according to the experimental

observations;

- *the consequences of the strategies*, determined by the action probabilities of each strategy;
- *a choice criterion*, where the decision-maker bases his choice for the best strategy.

Whenever decision-makers face problems without available or meaningful experimental data (no data problems), the above components *experiment*, *available strategies* and *consequences of the strategies* are irrelevant to the decision problem. In such cases subjective probabilities must be assigned (Halter & Dean, 1971), which creates the problem of differentation between risk and uncertainty, at least from an economic and statistical point of view, since such a distinction is considered a very important one by some anthropologists (Cancian, 1984).

The main target of classical decision theory, as far as statistics and normative economics are concerned, is to provide the decision-maker with the necessary criteria allowing him to take the best decision under his current level of knowledge of the states of nature, available choices, and consequences of each action. Several decision principles have been proposed, such as the Bayes principle and the minimax principle, which are among the most important (Berger, 1980).

The classical decision theory considered that rational behaviour was represented by the selection of the action associated with maximum expected utility, which coincides

with the maximum expected monetary value only when the utility function is linear (Halter & Dean, 1971). Under these circumstances maximising monetary value would be the decision criterion adopted by risk indifferent decision--makers (Mumford, 1978).

With a non-linear utility function risk averse decision--makers would probably adopt the minimax decision criterion (to minimise the maximum possible loss under the worst state of nature or, as the loss function can be represented in terms of gains, to maximise the minimum gain); on the contrary risk taker decision-makers would probably adopt the maximax decision criterion (to maximise the maximum gain under the most favourable state of nature) (Mumford, 1978).

After all, classical decision theory bases its behavioural predictions on the availability of a probability distribution of the states of nature, many times built on a subjective basis, and on the building of a utility function based on the decision-maker's preferences (involving again objective and subjective values) and, rationally, choosing the values which maximise the utility. However, the adoption of this approach to everyday decisions has been subject to many criticisms, coming from social scientists other than normative economists.

One conflicting point is linked with the rational objective of utility maximisation. Simon (1959) argues that individuals select actions resulting in satisfactory

outcomes instead of maximum results. If one argues that such behaviour is caused by a lack of information about all the relevant data, some psychologists claimed that even with perfect data people still have difficulty maximising a particular objective because of the limited information--processing abilities of human beings (Chibnik, 1984).

Another criticism presented by anthropologists and psychologists is linked with the use of probabilistic values associated with states of nature by decision-makers. They claim that alternatively, individuals use their heuristic knowledge, codified in rules of thumb, to make decisions without the necessity of probability calculus (Gladwin & Murtaugh, 1984), and without the need to rank all the available alternatives in terms of utility (Gladwin, 1984). Such criticisms reach a peak by questioning if man in his evaluation of evidence can be regarded as having a Bayesian behaviour at all (Kahneman & Tversky, 1972).

Not surprisingly, decision-making studies in crop protection range from works where the emphasis is put on describing the behavioural patterns and quantifying the farmers attitudes to control options, employing Fishbein behavioural predictive models (Tait, 1982; 1983) to normative economic studies (Carlson, 1970; Webster, 1977), whose objective is to indicate what action should be selected by a farmer making rational decisions.

4.2 - A CONCEPTUAL MODEL FOR DECISION-MAKING IN CROP PROTECTION

Norton (1976) became aware of the limitations linked with the adoption of the classical decision theory to explain crop protection decisions faced by growers, which he agrees are likely to be performed through an heuristic process leading to satisfactory results. Consequently, he proposed a more descriptive analysis to study the decision-making process concerning crop protection, adapting the general decision components indicated in Chapter 4.1 to this particular situation, and rewriting them as:

- *The farmer's goals*;
- *The range of crop protection measures he is to choose from*;
- *His perception of relevant information*;
- *The inferences he draws from the previous components in deriving expectations and making appropriate decision rules.*

This idea was further expanded later (Norton, 1982a; 1982b) and Norton & Mumford (1983) presented the conceptual model shown in Fig. 4.1, which has been fully explained and discussed in Norton & Mumford (1983), Mumford & Norton (1984) and Mumford (1987).

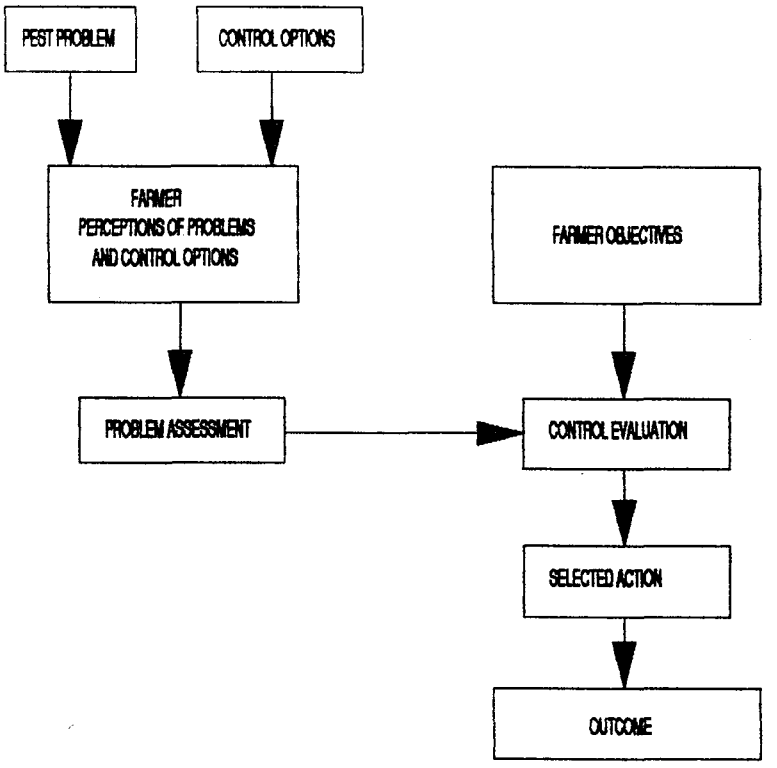


Fig. 4.1 - A conceptual decision model in crop protection
(Norton & Mumford, 1983).

The basic variables of the model are *farmer perceptions of pest problems*; *farmer perceptions of control options available*; and, *farmers objectives* (Norton & Mumford, 1983).

Pest problems are represented either as actual pest attacks or potential pest attacks, involving exogenous pests (many air-borne diseases and migratory arthropods that move to the crop from outside, and characteristically do not survive within the field from one crop to another) and endogenous pests (some arthropods, nematodes, soil-borne diseases and weeds, which remain within the field from one crop to another).

The options available to growers vary along the crop season and decisions about their use must be made in sequence, their range being reduced along the crop season by internal or external constraints (resistant cultivars can only be selected and in-furrow pesticide applications can only be done before sowing; some pesticides can only be applied in the beginning of the crop season for toxicological reasons). Such sequences of decisions can be represented very effectively for each particular case with a decision tree where all the available actions for the farmer are represented. A conceptual decision tree for a hypothetical pest problem affecting crop A is represented in Fig. 4.2, showing the decision nodes the farmer could face if all the existing technical information was made available to him in a "ready-to-use" format.

Farmer perceptions (in terms of actual or potential pests; actual or potential damage; and, effectiveness of control methods employed) represent the degree of knowledge achieved by the farmers. Such knowledge is the result of the experience accumulated by the farmer, either from the same or any other pest problem and crop, and from the information he obtains and accepts as useful (Mumford, 1982). When the farmer has a limited experience with the crop (new crop/new grower) he seems to be more pest problem oriented, while when his experience is considerable the farmer seems to be more option oriented (Norton & Mumford, 1983). Clearly, poor or incorrect perceptions can result in poor pest management decisions (Mumford, 1987). These

perceptions can be assessed through interview surveys of farmers (Norton, 1982b).

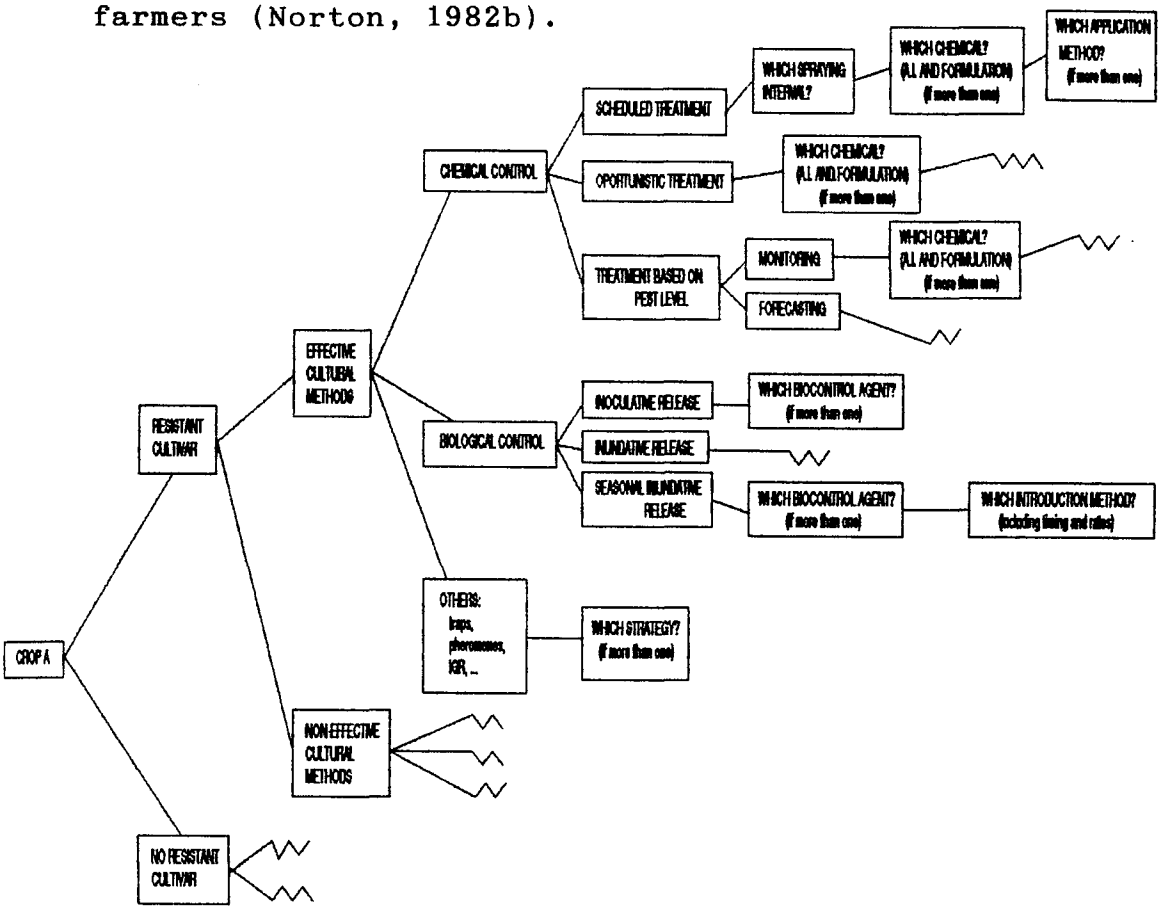


Fig. 4.2 - Conceptual decision tree for any pest problem affecting crop A.

Farmer objectives represent the achievements envisaged by the farmer, resulting from his judgements based on his own system of values. Norton & Mumford (1983) reported on two major groups of farmers: those with insurance objectives, trying to protect themselves from high potential losses; and, those with investment objectives, regarding pesticides as any other input providing positive returns.

The action selected depends on the way farmers assess (not involving judgement values yet) and evaluate (judgement values incorporated) the possible options.

If the outcome satisfies the farmer's objectives, the farmer is likely to maintain his pest control actions the same as long as his objectives and the assessment and evaluation of both pest problems and control options remain the same (Mumford & Norton, 1984).

That behaviour justifies the situations where farmers keep spraying the same pesticide, treatment after treatment, as long as they remain happy with the outcome and their perceptions of resistance problems remain unchanged.

As a result, the conceptual model presented in Fig. 4.1 and discussed above in a static form, must be considered in a dynamic way, taking account of experience resulting from previous outcomes in future decisions, and linking crop protection decisions with other management decisions made by the farmer (Norton & Mumford, 1983; Mumford & Norton, 1984).

4.3 - DECISION-MAKING IMPROVEMENT IN CROP PROTECTION

The major improvements in crop protection decision-making would result either from an increase in information on pests and available controls or from an improvement in the choice process of the decision-maker (Mumford, 1987).

The problems with information occur at several distinct levels: a) generating new information through research projects relevant to the pest problem; b) synthesising on

a "friendly" format all the information about the problem already available, in accordance with the information--processing abilities of the receptor farmers, allowing its understanding and acceptance; and, c) an effective dissemination of the information relevant to the problem's solution throughout the farming community, realising that different diffusion channels have different degrees of acceptance (verbal communication is usually rated higher than written information and electronic information sources usually get the lowest rates (Wearing, 1988)).

Since information gaps can occur at each of the information flow stages, it is convenient for analytical reasons to subdivide the "information gap" further into research gaps, synthesis gaps, dissemination gaps and reception gaps (Norton, 1982b).

According to its relevance to crop protection decision-making four types of information have been recognised (Norton, 1982b; Norton & Mumford, 1983):

- *fundamental information*, including basic biological, ecological and technical information about the pest problem and available control options;
- *historical information*, linked with records of pest attacks in the past (frequency and intensity) and related yields losses;
- *real time information*, resulting from monitoring activities and indicating the current state of pest density, crop growth stage, weather conditions, market prices,...;

- *forecasting information*, estimating the future development of pest populations and potential losses, based on information from the previous types mentioned. The time scale for the forecasting can be short term when dealing with exogenous pests at the farm level, medium term when dealing with endogenous pests at the farm level, and long term when the forecasting is extended to the regional or national levels either for exogenous or endogenous pests (Norton & Way, 1983).

The knowledge resulting from all the types of information described above can help farmers to improve their perception and assessment stages of the decision process (Mumford, 1987).

The second way to improve decision-making is through increasing the decision-maker's ability to choose. That can be achieved in three ways (Mumford, 1987): a) by training the decision-makers in the actual process of making decisions, through improvements to their basic education on pest management or to their abilities to structure the problems and assess the options; b) by employing crop protection specialists as decision-makers or advisors; and, c) by adopting "expert systems" to help define the problem, the available options and the appropriate actions to reach their objectives, providing at the same time training in the actual decision-making process.

The necessary improvements in the amount of available

information and on the decision process performed by the farmers will result from decision-oriented research activities, planned to cover research gaps and synthesis gaps, and from extension activities aware of any dissemination gaps and reception gaps.

Research activities in crop protection must be based on a clear understanding about the agricultural system involved, in terms of their major components and boundaries. A useful methodological approach to identify research and extension needs based on such understanding of agricultural systems has been the "soft" system analysis approach, suggested by Norton (1982b) and discussed in Norton & Mumford (1983), Norton (1987) and Teng (1987). "Soft" in this sense means that this approach does not rely on extensive computer modelling and simulation, being particularly suited for analysis of systems with ..."*goals not clearly recognisable and outcomes ambiguous or uncertain*"..., and is typically associated with unstructured problems linked with human activities (Teng, 1987).

The major components of a "soft" systems analysis approach are represented in Fig. 4.3. By synthesising and analysing existing information on biological, ecological and technical factors and farmers' circumstances through this approach, the researcher can identify the key-questions relevant to farmers current problems and adjust future research projects to those key-questions.

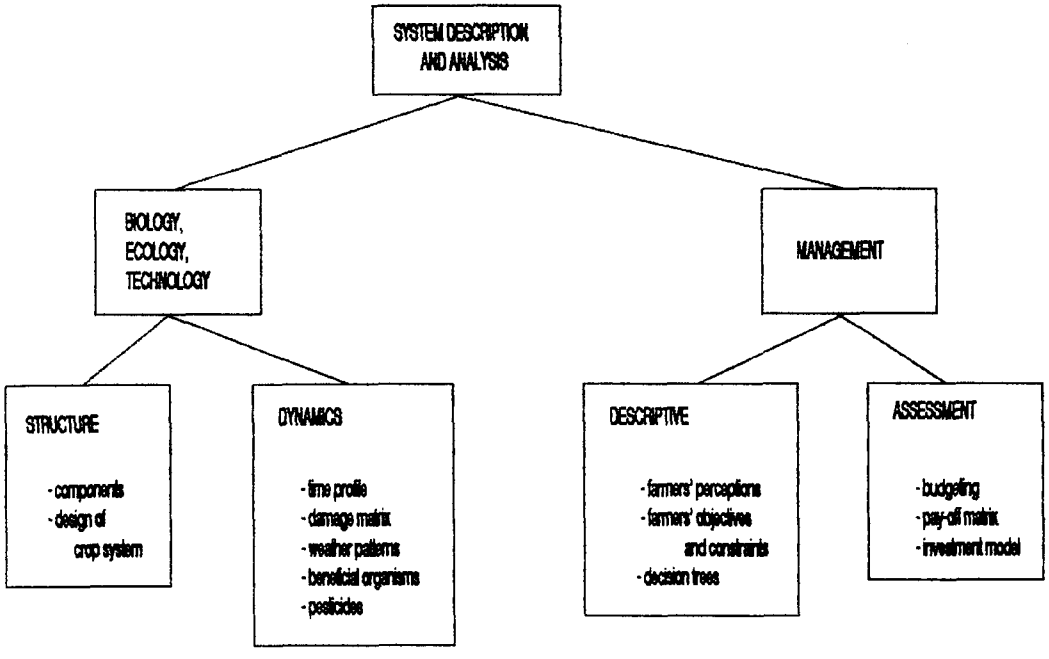


Fig. 4.3 - Major components of a "soft" systems analysis approach (Norton, 1982b; Teng, 1987)

Extension activities are essentially confronted with a diffusion problem, promoting the adoption of new technology throughout the farmers' community. The rates of diffusion of new technology in agriculture are dependent, apart from available information discussed above, on capital aspects linked with the adoption of the innovation (capital saving/ / no capital changing / additional capital), existent management skills, profitability and riskiness and/or uncertain associated with the adoption (Byerlee & de Polanco, 1986; Hill & Ray, 1987).

The adoption process is commonly represented by a sigmoid curve (Hill & Ray, 1987), depending on the time of

adoption's initiation and the rate at which adoption occurs (Byerlee & de Polanco, 1986). When such cumulative adoption distribution is represented on a *per time unit* scale the usual "normal" type curve for diffusion distribution is achieved.

In this classical diffusion model the first farmers to adopt the innovation are called innovators (the first few percent ($\pm$ 2.5% if the distribution is normal)); the following farmers are the early adopters (14% under normal distribution); and then the majority of the farmers earlier or later accepts the changing (67% under normal distribution). The remaining group (16.5% under normal distribution) is composed of those who are the last to adopt or never adopt (Hill & Ray, 1987).

These authors indicate the general characteristics of the farmers in each of the categories concerning personal attributes, social relationships and values as well as communication behaviour. The innovators in particular are characterised as having the highest social status, well educated, often young, wealthy, willing to accept risks, some leadership capacities and well informed, interacting with other innovators. Farmers who innovate with one specific technology tend to maintain this behaviour for many other new technologies (Hill & Ray, 1987).

Having defined innovators like that it is expected that innovations will be first adopted by larger and more prosperous farmers since they can handle better the risk

associated with innovation (Byerlee & de Polanco, 1986; Hill & Ray, 1987).

However some anthropologists, while considering the distinction between risk and uncertainty very important, as stated in Chapter 4.1 (linking the risk concept with the natural variability occurring in the farmers' environment, like rainfall; and the uncertainty concept with the potential variability associated with the innovation itself) and the wealth rank inside the farmers' community, predicted that in the early phase of an adoption when uncertainty is high, low-middle rank farmers will have a higher adoption rate than the high-middle rank farmers. In the later stages of the adoption when uncertainty is low the rich farmers should be relatively faster adopters than the poor farmers (Cancian, 1984).

The basic assumptions of the classical diffusion model states that the innovation will spread through imitation throughout the farmers' community as a function of the number of contacts between adopters and non-adopters, which will be proportional to the numbers included in each category in an intermixed and homogeneous population situation (Akinola, 1986).

However, in "real life" situations with heterogeneous social structures the number of contacts between members of some social group (eg. inside the family; social groups of local importance; church) may be very high but outside these groups the number of contacts can be fewer than would

be expected under the assumptions of the classical diffusion model. As a result several parallel diffusion channels can occur in the same region, basically dependent on the behaviour of two distinct groups: the innovators and the imitators.

In view of this the innovator-imitator diffusion model can be regarded as a better theoretical framework to explain diffusion of agricultural innovations. The model does not assume any *a priori* shape distribution and their parameters can be estimated from discrete time series data (Akinola, 1986). Unfortunately, it seems that such a model does not perform statistically better than the classical diffusion model when applied to predict specific diffusion cases, as Akinola (1986) found.

In crop protection the adoption of new technologies can occur due to several main conditions (Norton, 1982b): a) on-farm "crisis" situations, resulting from new pest problems or increased attacks of current pests, failure of present control methods, development and availability of completely new control methods; b) on-farm general improvement situation, resulting from gradual increase of farmers' perceptions and assessment of pest problems and control options available; c) off-farm technological packages, imposed on farmers by governmental or private schemes linked with development programmes.

It must be stressed that even with package situations, farmers seem to adopt the different technological

components in a stepwise manner, the sequence of adoption being dependent on profitability and riskiness characteristics associated with each technological component (Byerlee & de Polanco, 1986).

The adoption process of a new technology at the individual level is commonly divided in several stages involving : *awareness of innovation; formation of interest on the innovation and gathering of information; decision to adopt or reject; the actual use of the innovation* (Lambur *et al.*, 1985; Hill & Ray, 1987).

The extension effort should then be concentrated on the diffusion of appropriate technology fitting the farmers' needs, according to their particular conditions, through the most appropriate communication channels in order to increase awareness, interest and available information at the farmers' level.

Two major categories of communication channels can be considered for extension purposes: *mass media channels* (allowing few individuals to reach a big audience by radio, Tv, newspapers, journals and computers) and *interpersonal channels* (involving a face-to-face exchange of information between two individuals) (Lambur *et al.*, 1985). According to these authors communication channels of the former category are intended to increase awareness of the innovation and provide general information; the latter category is more important on formation of interest, decision to adopt or reject and actual use stages. A

particularly successful way to develop IPM projects seems to be by cooperative programmes implemented through strong producers' organisations (Wearing, 1988).

5 — SURVEY OF GROWERS' DECISION-MAKING

5.1 - INTRODUCTION

Farmer surveys have been widely used as a technique to obtain information and understanding of the farmers' circumstances. Either general agricultural circumstances (Byerlee *et al.*, 1980) or those specifically related to pest problems and decision processes at the farm level can be investigated by this method (Mumford, 1978; Lane, 1981; Tait, 1983; Jusoh, 1984; Heong, 1984; Javaid *et al*, 1987).

Reichelderfer *et al.* (1984) listed the advantages of performing a farmer survey at the initial stage of an integrated pest control research and extension programme:

- *description of farmers perceptions, needs, objectives and resource constraints* (internal farmer circumstances);
- *information on current pest control methods employed*;
- *identification of research gaps on major pest problems perceived by farmers*;
- *identification of information gaps at the farm level.*

The recent development of the greenhouse industry in Portugal, described in Chapter 3, was followed by some research efforts in the late 1970's, particularly in the Algarve region. However, that research mainly concentrated on production aspects and costs of the crops; research

programmes involving crop protection activities in greenhouses were very scarce until the mid 1980's. Furthermore, information about the greenhouse production system was almost non-existent for the West region. Finally, information about farmers' personal decision--making was also unavailable or nonexistent, irrespective of geographical location.

Under these conditions, the execution of a survey of greenhouse growers was regarded as a necessary methodological approach for studying their pest control decision-making. It can also serve as the initial phase for future IPM projects (Reichelderfer *et al.*, 1984) or on--farm research programmes (Byerlee *et al.*, 1980) involving greenhouse crops in Portugal.

5.2 - THE INTERVIEW SURVEY

A personal interview survey of growers was conducted in Portugal, in the Algarve and the West, during the Autumn of 1987, to obtain information about the production system used by the growers and to understand the key pest problems with which they are confronted, how they perceive them and the options they have to reduce yield losses caused by the pests, according to the conceptual model discussed in Chapter 4.2. Both areas were selected because they are the most important in the country in terms of greenhouse vegetable area, as shown in Fig. 3.1 and Table 3.3.

The necessary exploratory survey (Byerlee *et al.*, 1980), performed to obtain a preliminary understanding of the farming system, cultural practices and major constraints of the greenhouse industry in Portugal, pest problems included, was done during the second half of November and December, 1986. During this period several informal interviews were done involving growers, technical officers and researchers from the Ministry of Agriculture, Universities and private companies. The information collected through this procedure, together with all the secondary data obtained in Portugal from publications and available unpublished reports concerning greenhouse production, was used as background information for structuring the survey questionnaire and planning the formal survey.

The final version of the written questionnaire used in the formal survey is presented in Appendix II (2.1 - Portuguese version; 2.2 - English version). It consists of five distinct sections, with a total of 44 questions. Some questions are organised like tables, allowing the adjustment of particular questions to specific crops and pest problems according to the growers' conditions (eg. questions no 11 and 14). Many questions are presented as multiple-choice questions, allowing easy marking during the interview. The remaining are open-ended questions. Advantages and disadvantages of the different types of questions, as well as other aspects of questionnaire design are discussed in detail in several publications (Oppenheim,

1966; Tull & Hawkins, 1987).

The first nine questions of the questionnaire (Section I) try to characterise the greenhouse environment in the regions under study with protected vegetable crops and the agricultural pattern of the areas, the type of greenhouse structures and the cultural practices used by the growers through their normal production activities.

The second section of the questionnaire includes 12 questions and is intended to indicate the pest problems perceived by growers, how they assess them in terms of importance and what control methods they use against the key pests.

The third section, with nine questions, tries to determine: how growers obtain information about pest problems and control methods; difficulties in obtaining information; difficulties they face to solve pest problems; and how they assess the efficacy of the chemicals applied as well as the application methods used.

The fourth section of the questionnaire, with four questions, is intended to clarify the growers expectations in the near future concerning pest problems and their effects, as well as to identify the main needs which could improve growers pest control actions.

Finally the fifth section, with ten questions, is designed to characterise the growers' age, educational background and identify their assessments of different pest control

options and their general attitude to economic risk.

The initial versions of the questionnaire were made in English. When a version ready for pre-testing was obtained it was translated to Portuguese and pre-tested under Portuguese conditions (late September, earlier October 1987). Four growers were interviewed during the pre--testing (...*five or so growers should be interviewed for questionnaire pre-testing*... (Byerlee *et al.*, 1980)). Focus was mainly on the questionnaire fluency, question sequence and growers understanding of the questions. The final version was translated back to English later.

Once the final version of the survey questionnaire was obtained all the necessary planning and arrangements for survey implementation were done (October, 1987).

A sample size of 30-50 farmers for each "recommendation domain" (...*a group of roughly homogeneous farmers with similar circumstances for whom we can make more or less the same recommendation*... (Byerlee *et al.*, 1980; Harrington & Tripp, 1984)) has been proposed in technical manuals for this type of survey (Byerlee *et al.*, 1980; Reichelderfer *et al.*, 1984), or at least 25-30 farmers for each "recommendation domain" (Harrington & Tripp, 1984), since ...*well known statistical rules for determining sample size on the basis of the variability within the sample can not be formally applied for this type of surveys*... (Byerlee *et al.*, 1980). By contrast, the sample size is dependent on praticability, linked with resources and time available.

In the West lists of growers were obtained from two regional Cooperatives, from pesticide companies local representatives and from local growers. Growers were then selected randomly and those selected were visited with technical officers from the Cooperatives, from the pesticide companies or with local growers, which helped to introduce the survey objectives to the growers, trying to obtain their participation and arranging a convenient timetable for the grower to perform the interview.

In the Algarve the growers were selected at random based on randomised lists of growers available from previous studies on greenhouse production costs conducted in the Algarve by researchers from the regional offices of the Ministry of Agriculture. With the support of those researchers and the local extension officers, the selected growers were visited, introduced to the objectives of the survey and a convenient time for an interview was arranged with the grower.

Through this procedure it was possible to interview 32 growers in the West and 29 in the Algarve, located as shown in Figs. 5.1 and 5.2. The actual interviewing took three weeks in each region (November and December, 1987), in agreement with the usual average reached in formal surveys (between one and two interviews per day (Byerlee *et al.*, 1980)).

The formal interviews lasted between 1hr and 1.5 hr but in a great number of cases once the questionnaire finished the

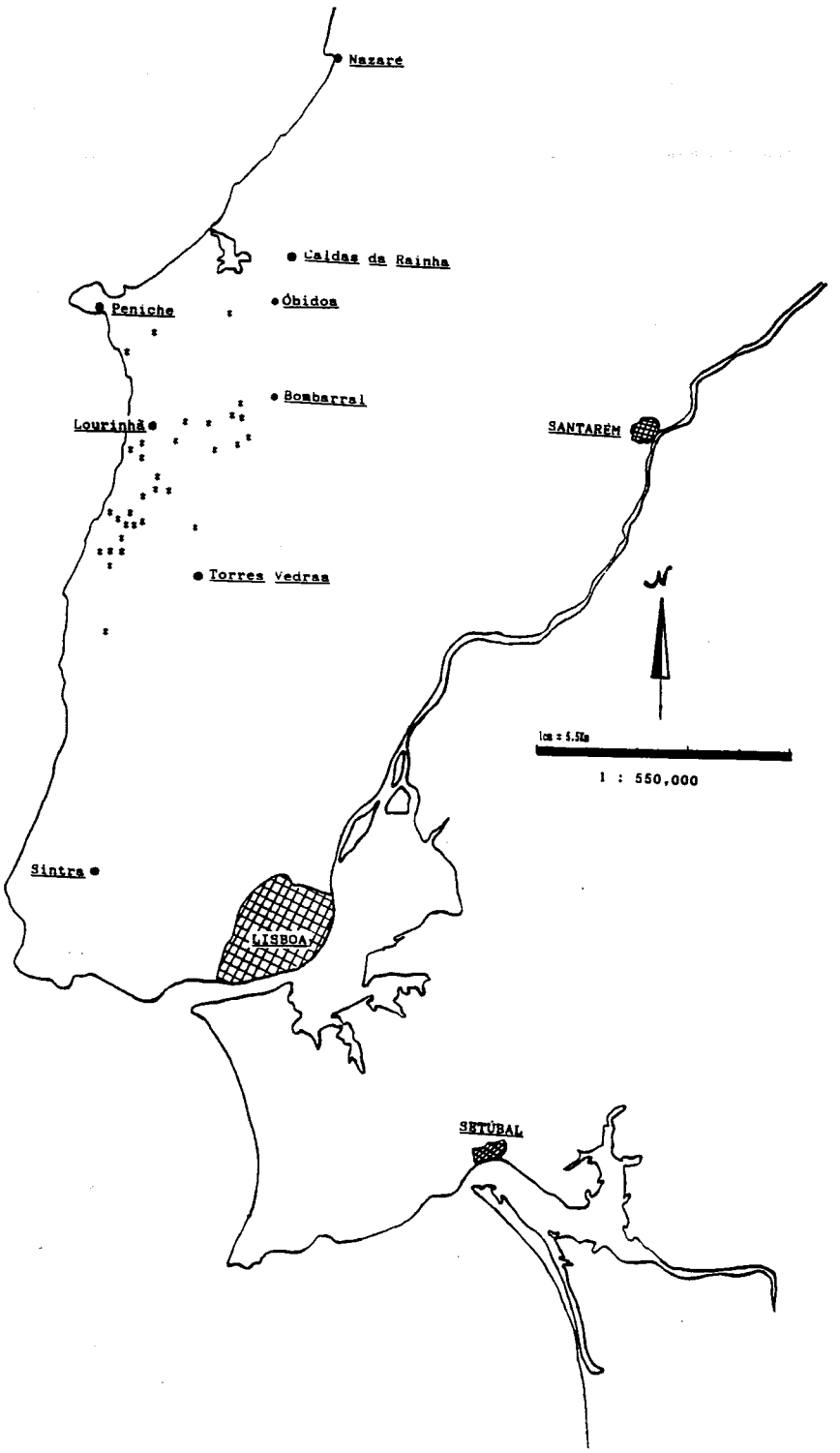


Fig. 5.1 - Location of the growers interviewed in the West
(each * represents one grower)

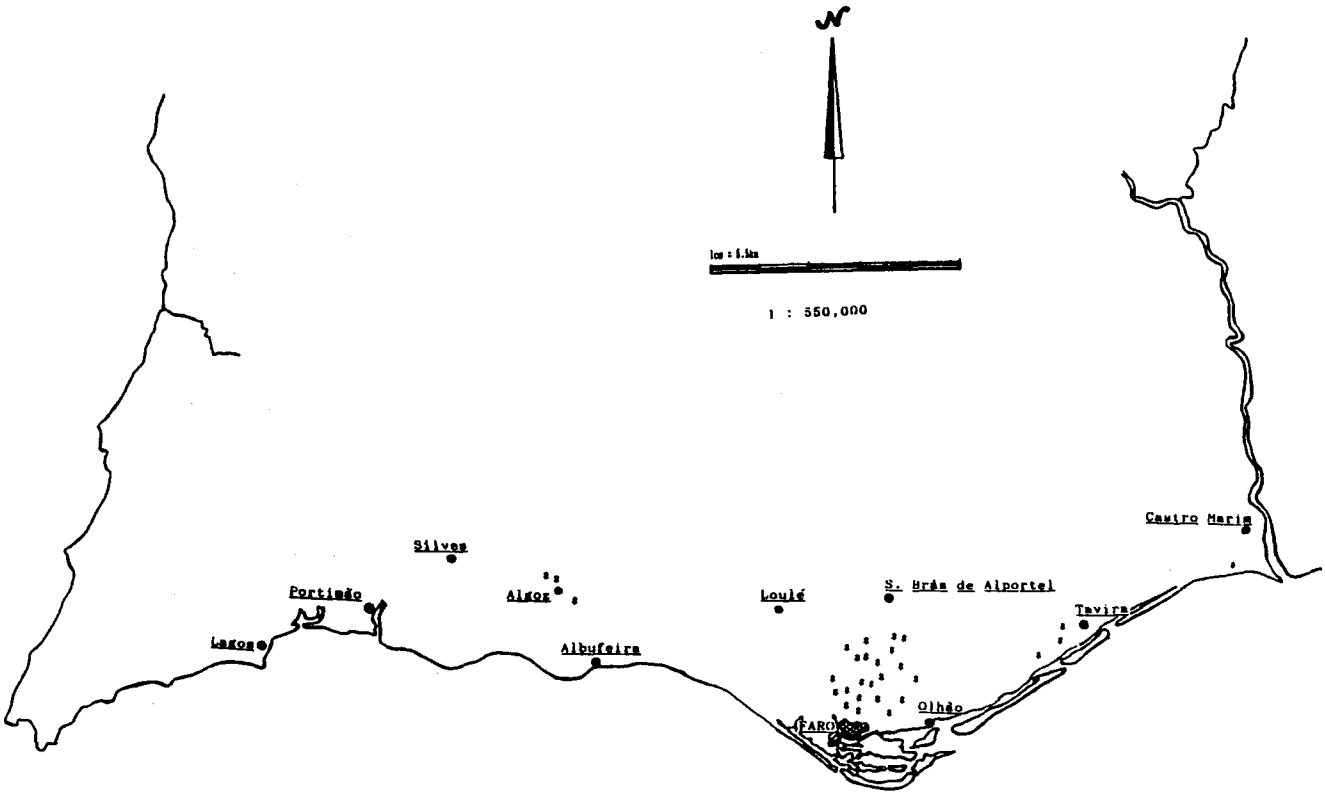


Fig. 5.2 - Location of the growers interviewed in the Algarve
(each * represents one grower)

conversation with the growers continued, including inclusive visits to greenhouse crops and discussions *in loco* about problems faced by the grower. All the growers contacted, except one in the Algarve, were very cooperative in providing information and discussing their problems.

Because it is recognised that is almost impossible to obtain data about labour inputs and needs through the year in a single interview (Byerlee *et al.*, 1980) no question was included in the survey questionnaire on labour needs and difficulties. However, in the Algarve the majority of

the growers referred to this point during the interview conversation and it seems that this problem is becoming a major worry for the growers. In the West some growers are beginning to have labour difficulties, particularly in some periods and crops (ex: picking up pods of green beans which is an intensive labour demanding activity).

The editing and coding of the questionnaire data was done after the formal survey, question by question, to a microcomputer using the data management package **dBase III** (Ashton-Tate, 1984) to create a structure for data display and analysis. Detailed discussions about data editing and coding can be found in Jolliffe (1986) and Tull & Hawkins (1987).

The objective of the analysis was to test differences between both regions under study and between particular groups of growers in the sample. The type of data collected through the questionnaire involves mainly nominal measurements and ordinal measurements, with very few questions involving interval measurements. According to the data, statistical analysis was performed using descriptive measures such as *mode* , *frequency* or *mean*, and the statistical tests Chi-square for two independent samples, Fisher exact test, and *t*-test were used when appropriate (Siegel, 1956; Tull & Hawkins, 1987). As some questions were only answered by a few growers, computations in these cases were only based on the actual number of growers responding to each question and not on the total sample size.

The information provided by growers about weed species presented in greenhouses was recorded according to the common names used by the growers. The conversion from common names into scientific names was performed later, based on works published by Rocha (1979) and Moreira *et al.* (1986). When the common name mentioned by growers was doubtful it was checked out using the weed photographs presented in Moreira *et al.* (1986).

5.3 - RESULTS OF THE SURVEY

The analysis of the survey questions follows a different order from the actual questionnaire sequence in many cases. The reason for that is that the questionnaire order was designed bearing in mind the sequence of conversation with the growers, as informal and clear as possible, beginning with general, easy to answer questions, going on to more specific questions, with more difficult answers.

The analysis tries to create a general structure to describe: i) the greenhouse environment, ii) the production system, iii) the growers, iv) the pest problems they perceive, v) the solutions applied to solve these problems, vi) the growers' difficulties and attitudes concerning crop protection methods, and, vii) their expectations for the future of pest problems and crop protection practices.

5.3.1 - Greenhouse environment

Both of the regions studied present a diversified agricultural pattern with several crops and cropping systems coexisting in the same area. Animal husbandry is also an important agricultural activity in the West. To assess the spatial diversity of crops near greenhouses, growers were asked about the existing crops on neighbouring farms (question no. 7).

On average each grower indicated 4.0 different crops in the West and 5.6 different crops in the Algarve. In the Algarve most growers indicated greenhouse crops on neighbouring farms (tomato, melon, green beans and, to some extent, sweet pepper) as well as orchards, particularly citrus orchards, while in the West the most abundant crops around the farms with greenhouses are vineyards, potatoes and orchards. However, in the West, unlike the Algarve situation, they are mainly pear and apple orchards (Fig. 5.3).

While in the Algarve 79% (22/28) of the growers answering this question have greenhouses around their farms, only 33% (11/32) of the growers surveyed in the West have greenhouses around their farms, mainly with tomato and green beans. This difference between the proportion of growers with greenhouses nearby is very significant ($p = 0.002$), suggesting that greenhouse distribution is more dispersed in the West than in the Algarve.

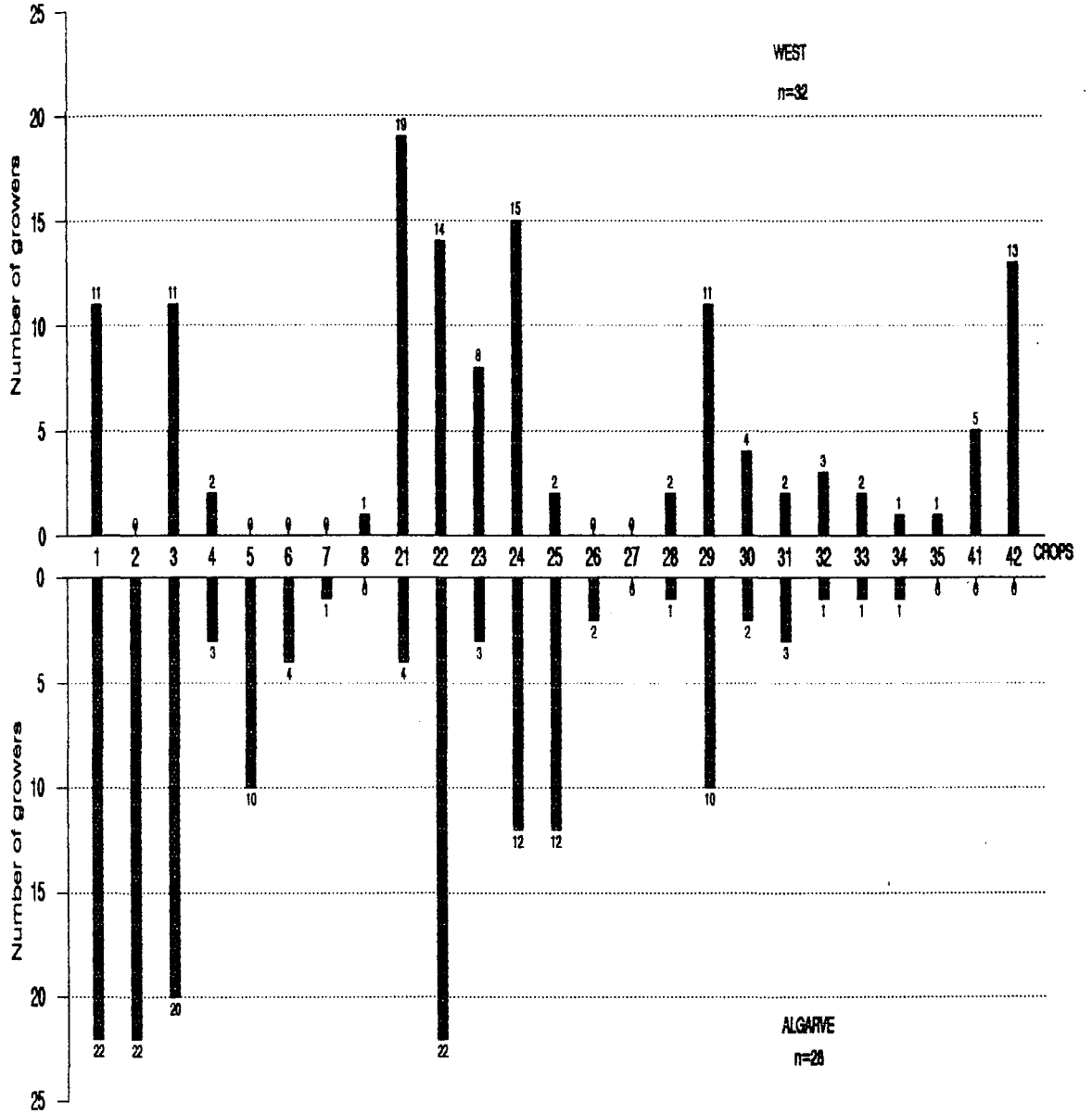


Fig. 5.3 - Common crops near greenhouses

Crops :

- 1 - Tomato
- 2 - Melon
- 3 - Green beans
- 4 - Lettuce
- 5 - Sweet pepper
- 6 - Cucumber
- 7 - Strawberries
- 8 - Ornamentals

} Greenhouse crops

- 21 - Vineyard
- 22 - Orchards
- 23 - Cereals
- 24 - Potatoes
- 25 - Broad beans
- 26 - Tomato
- 27 - Melon
- 28 - Strawberries
- 29 - Cabbages
- 30 - Carrots
- 31 - Lettuce
- 32 - Peas
- 33 - Green beans
- 34 - Onions
- 35 - Pasture

} Field crops

- 41 - Pines
- 42 - Eucalyptus

} Forestry

Forestry areas, particularly eucalyptus, are also common in the West (Fig. 5.3), which is quite convenient for the growers, since the wood used in the structure of Portuguese greenhouses is mainly eucalyptus timber without any preservation treatment.

Other crops frequently referred to by growers in the West are cabbages and cereals (oats, wheat and barley) while in the Algarve potatoes, broad beans and cabbages are also frequent crops in the neighbourhood of greenhouses (Fig. 5.3).

Another important feature of the greenhouse environment is that half of the growers, in both regions (17 growers in the West and 13 in the Algarve), also grow the same vegetables they produce inside the greenhouses in the open, especially green beans, lettuce and tomato in the West and melon and tomato in the Algarve (question no. 6). In the latter region lettuce is mainly produced in the open by specialised growers in large areas; water-melon is also produced in the open around greenhouses by many growers (Table 5.1).

This pattern could be explained by the fact that many of the growers were already vegetable producers with open fields (see Chapter 3.2) and this could be an important factor in the development of the key pest problems.

Table 5.1 - Crops and average areas produced in open fields, on the same farm by surveyed growers

\REGION \ CROPS \	WEST		ALGARVE	
	No. of growers	Average area (m^2)	No. of growers	Average area (m^2)
Green beans	10	4,610		
Lettuce	5	6,700	2	50,000
Melon			11	9,636
Tomato	4	5,875	8	11,375
Water-melon			5	14,200

5.3.2 - Distribution of greenhouse area and soil type

All the growers surveyed in the West had a greenhouse area smaller than 5 ha (question no. 2), while in the Algarve 7% of them had an area bigger than 5 ha (Table 5.2), as expected from information discussed in Chapter 3.2.

Zettelmeyer & Henriques (1986) found the distribution of greenhouse area in the Algarve had the larger classes of area more represented, as shown in Table 5.2. An explanation for the discrepancy observed in the two studies in the Algarve could be due to the randomised lists of growers obtained from the regional services of the Ministry of Agriculture in the Algarve contained mainly the growers from smaller area classes, which was recognised by Henriques (*pers. comm.*). While this limited the

information obtained from the larger area classes in the Algarve, it allows comparison of growers from the same area classes and similar conditions in both regions of the country (growers of the same "recommendation domain", according to the CIMMYT terminology (Byerlee *et al.*, 1980)).

Table 5.2 - Distribution of greenhouse area owned by the surveyed growers

% of cases \ Class of area (ha)		≤1	>1-5	>5-10	>10-25	>25	No. of growers
Present Survey	West	72	28	0	0	0	32
	Algarve	52	41	7	0	0	29
Zettelmeyer & Henriques (1986)	Algarve	10.4	53.4	18.9	11.8	5.5	484

In the West the average number of years growers have been producing vegetables in greenhouses in the area class >1-5 ha is 6.2 years while for the class ≤1 ha it is 3.0 years, which supports the idea that originally growers began with a small covered area and gradually, as they got experience and profits to reinvest in the industry, they increase the greenhouse area. In the Algarve this is not so obvious, with 9.5 years of production on average for the area class >1-5 ha and 8.5 years on average for the class ≤1 ha.

However, if the data presented in Table 3.5 is considered the same pattern is found, with the holdings belonging to the class of area >5-10 ha being established later, on average only 6.2 years ago.

None of the interviewed growers use non-soil production techniques (ex: peat compost bags or straw-bales, rockwool with a nutrient solution) and the answers about the type of soil that the growers have inside greenhouses (question no. 9) could be codified in five categories: sandy, sandy--loam, loam, clay-loam and clay soils. In the West the most common soils are sandy or sandy-loam soils while in the Algarve it is mainly clay with some patches of sandy soils (Table 5.3). In both regions a quarter of the growers have more than one type of soil in their greenhouses (8 growers in the West and 7 in the Algarve) which creates additional difficulties in fertilisation and irrigation.

Greenhouses first appeared on sandy soils in both regions but they quickly spread to other soil types: i) in the Algarve the average number of years the surveyed growers have been producing vegetables in greenhouses is 10.9 on sandy soils, 8 years on clay soils and 6.8 years on clay--loam soils; ii) in the West the average number of years the surveyed growers have been producing vegetables in greenhouses is 4.7 years on sandy soils, 3.7 years on clay soils, 3.1 years on sandy-loam soils, 3.2 years on clay--loam soils and 2.8 years on loam soils.

Table 5.3 - Number of growers in both regions indicating each soil type.

types\region of soil\	WEST	ALGARVE
CLAY	10	25
CLAY - LOAM	5	2
LOAM	2	0
SANDY - LOAM	10	0
SANDY	14	9

5.3.3 - Greenhouse structures

The type of greenhouse structure mainly used by the growers (question no. 8) is a wooden structure with a saddle-roof built either as a single span or as a multiple span, the former being the predominant form in the West (28 of the 32 growers have this structure) (Fig. 5.4) while the latter is the most common structure in the Algarve (Fig. 5.5) (Table 5.4).

In the Algarve in the last three-four years 21% of the surveyed growers (6/29) changed the greenhouse structure type and the same percentage of growers use two different types of structure. No grower indicated the use of metal in the structure of the greenhouses, which is in accordance with the results published by Zettelmeyer & Henriques (1986) who found that only 1.2% of the cases surveyed by them had metal components in the greenhouse structures.

In the West 34% of the interviewed growers (11/32) had changed the type of structure in the last three-four years, trying to adapt other structure types to the environmental conditions of the area and 31% of them (10/32) use two different types of structures. One of the alternative structures built by the growers in the West is a local adaptation of the Spanish "Parral" type (7 growers of the surveyed group had this type of greenhouse in the West). This structure allows the grower to cover bigger areas with a single structure, varying from 1,200 m^2 to 6,000 m^2 on the surveyed farms, and fits well on the slopes of the small hills which are abundant in the West without needing huge movements of soil. Better resistance to the wind and better conditions for mechanisation inside the greenhouse were among the reasons given by growers to justify this type of structure despite its higher price compared to the common single span.

This "Parral" structure is widely used in Spain (Almeria region) where it has either a flat roof or a small roof slope in accordance with the low rainfall of that area. However, the annual rainfall in the West is at least two times greater than in Almeria and the growers try to solve this problem by increasing the pitch of the roof (Fig. 5.6).

Other structures recently used in the West have round metal arches at the roof with vertical walls supported by wooden poles, either as a single-span (5 growers) (Fig. 5.7) or as a multiple-span (1 grower) (Fig. 5.8), which are even more

expensive than the "Parral" type.



Fig 5.4 - The predominant greenhouse structure in the West



Fig. 5.5 - Multiple-span greenhouse structure common in the Algarve

Table 5.4 - Occurrence of different types of structures in both areas, as a % of cases declared by the surveyed growers.

% of cases \ Type of structure		A	B	C	D	E
Present Survey	West	68	12	0	3	17
	Algarve	47	0	53	0	0
Zettelmeyer & Henriques (1986)	Algarve	50		50		0

Types of greenhouse structures : A - single-span wood structure of the saddle-roof type
B - single-span structure with round metal arches at the roof supported by vertical wood poles
C - multiple-span wood structure of the saddle-roof type
D - multiple-span structure with round metal arches at the roof supported by vertical wood poles
E - "Parral" type of structure

All the surveyed growers in both regions use polythene materials to cover the greenhouses (question no. 8) and the most used polythene types, irrespective of size class and region, are the long-life polythene (treated with stabilisers, mainly u.v. absorbent substances) and the "thermal" polythene (treated with long infra-red absorbent substances and "thermic charges", like aluminium silicate or magnesium silicate (Nisen *et al*, 1988)).

The standard polythene, used in the country in the early days of the greenhouse industry, is no longer applied to cover greenhouses (Table 5.5).



Fig. 5.6 - "Parral" structure adopted in the West



Fig. 5.7 - Greenhouse single-span structure with round metal arches at the roof, adopted in the West

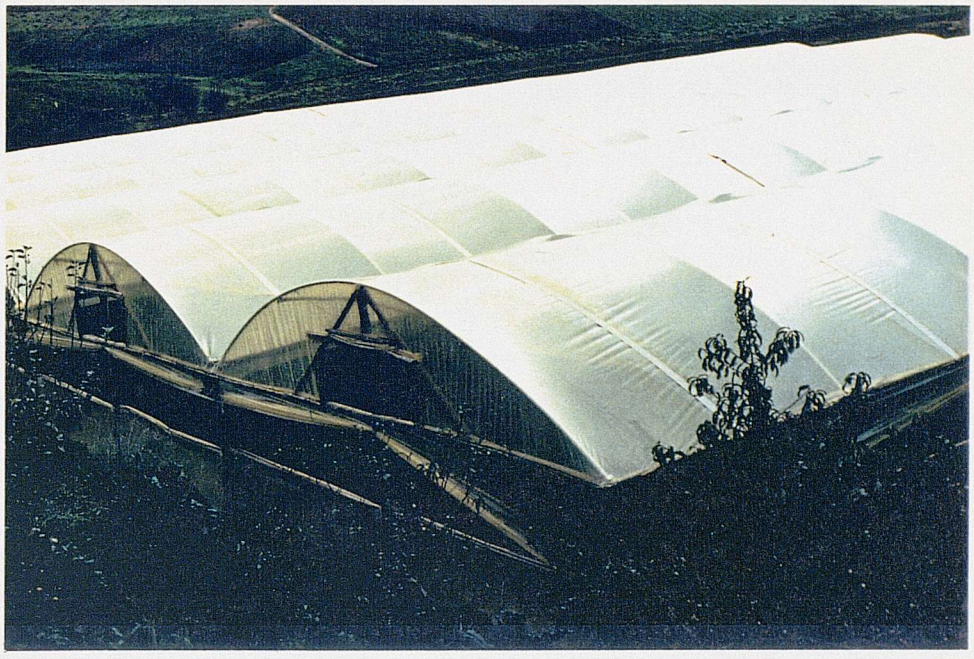


Fig. 5.8 - Greenhouse multiple-span structure with round metal arches at the roof, adopted in the West

In the two regions the use of long-life polythene is associated with growers who have been in this agricultural activity for a longer time (on average 10 years in the Algarve and 5.7 years in the West) while the "thermal" polythene is used by growers coming to the industry later (6.7 years in the Algarve and 2.7 years in the West on average) which could result from the fact that the "thermal" polythene film was developed later than the long--life polythene.

On average the long-life polythene lasts two years in both areas (2 years in the West and 2.1 years in the Algarve) and the "thermal" polythene lasts 2.8 years in both areas, according to the growers. Based on this average duration a

grower can expect an extra 33%-40% of life time for the plastic covering the greenhouse if he invests a further 11% per kg of plastic (considering the prices indicated by the growers in the West, in 1987 (long-life polythene - Esc. 280 kg^{-1}, and "thermal" polythene - Esc. 330 kg^{-1}) and assuming that long-life polythene films have the same thickness of "thermal" films (0.20 mm); otherwise, the difference in plastic prices could represent either an increase of 32.5% per m^2 if long-life polythene has a thickness of 0.18 mm, or an increase of 57% per m^2 if long--life polythene has a thickness of 0.15 mm, assuming the normal density for the polythene of 0.92).

Table 5.5 - Type of plastic used by the growers to cover the greenhouses, expressed as a % of the cases declared by the growers.

% of cases \ Type of plastic			A	B	C
Present Survey		West	67	33	0
		Algarve	63	37	0
Zettelmeyer & Henriques (1986)		Algarve	38	53	9

Types of plastic: A - long-life polythene (treated anti-u.v.)
B - "thermal" polythene
C - normal polythene (standard)

In both areas the growers use natural ventilation (question no. 8) through windows opened along the side walls and gables of the greenhouses (Table 5.6). In the West some

growers who have metal structures at the roof also have a ventilation opening along the top of the roof to improve lateral ventilation. The "Parral" structure has a window all around the walls.

Table 5.6 - Ventilation types used in the greenhouses, as a % of the cases declared by the growers

% of cases \ Type of ventilation			A	B	C*	D*
Present Survey		West	34	57	6	3
		Algarve	7	93	0	0
Zettelmeyer & Henriques (1986)		Algarve	99.8		0.2	

Types of ventilation : A - side-wall windows
B - side-wall and gable windows
C - side-wall, gable windows and top roof ventilation
D - side-wall windows and top roof ventilation
* - these ventilation systems were always linked with the structures with metal arches at the roof

5.3.4 - Crops and cultural practices

5.3.4.1 - Major crops

The crops grown by the surveyed farmers in both areas (question no. 3) are indicated in Table 5.7. Tomato is the major crop for all growers in both areas. In the Algarve melon, green beans and sweet pepper are also common crops and cucumber is frequent. Lettuce is poorly represented in

Table 5.7 - Greenhouse crops produced by the growers in the studied areas

% of cases	CROPS		TOMATO	MELON	GREEN BEANS	LETTUCE	SWEET PEPPER	CUCUMBER	BANANA	STRAW-BERRIES
	Present Survey	West	100	31	84	31	21	19		6
		(*)	(32)	(10)	(27)	(10)	(7)	(6)		(2)
		Algarve	100	86	83	6	73	45	6	
		(*)	(29)	(25)	(24)	(2)	(21)	(13)	(2)	
	Zettelmeyer & Henriques (1988)	Algarve	100	70	59	8	33	33		1

(*) - Number of surveyed growers with this crop or planning to grow it this year

greenhouses (2 growers), being grown mainly in the open, and 2 growers have high expectations for the banana crop inside greenhouses and they keep some covered area with bananas (Fig. 5.9) (one grower especially brought sword suckers from Madeira Island to begin the crop).

In the West green beans are the second most important crop, while 31% of the growers have melons or lettuce; sweet pepper and cucumber are grown only by one fifth of the growers in this region.

In the West tomato is mainly cultivated as a winter crop (Table 5.8) and green beans are the most important spring crop for both sizes of farm; sweet pepper is mainly grown by the farmers with between 1 ha and 5 ha. Cucumber and

melon are mainly grown in the spring season but some growers also try these crops on a winter cycle in smaller areas (Table 5.8).



Fig. 5.9 - Banana crop in a plastic greenhouse in the Algarve

In the Algarve tomato is the most important crop in the winter season but in the spring it loses importance particularly for growers with larger areas; green beans are also grown in larger areas during winter than in the spring for all size classes. Melon seems to be grown only as a spring crop in the Algarve while lettuce is a winter crop grown mainly by growers with less than 1 ha. In this region the majority of the growers prefer to produce the sweet pepper crop during the winter; however, the spring crop is grown in larger areas. Cucumber, like melon, is essentially a spring crop (Table 5.8).

Table 5.8 - Average areas (m^2) grown by season and class of area of the major crops produced in both areas

Region	Class of area (ha)	Season	TOMATO		MELON		GREEN BEANS		LETTUCE	SWEET PEPPER		CUCUMBER		BANANA	STRAWBERRY
			winter	spring	winter	spring	winter	spring	winter	winter	spring	winter	spring		
WEST	<1		3295	1909	0	1098	553	2146	930	0	400	100	658	0	0
		(*)	(23)	(14)		(5)	(2)	(17)	(6)		(2)	(1)	(5)		
	>1-5		17522	7684	1300	2325	1800	10593	10000	2440	3067	600	2000	0	5000
		(*)	(9)	(9)	(1)	(4)	(1)	(9)	(1)	(4)	(3)	(1)	(1)		(1)
	Total for the region	(*)	7297 (32)	4169 (23)	1300 (1)	1644 (9)	969 (3)	5070 (26)	2226 (7)	2440 (4)	2000 (5)	350 (2)	882 (6)	0	5000 (1)
ALGARVE	<1		1848	1532	0	1540	1259	786	465	579	939	0	428	2000	0
		(*)	(14)	(5)		(12)	(6)	(7)	(2)	(6)	(2)		(4)	(1)	
	>1-5		7108	2795	0	4738	3340	2534	0	1286	2700	513	902	1120	0
		(*)	(12)	(4)		(10)	(4)	(7)		(9)	(2)	(3)	(5)	(1)	
	>5-10		45000	0	0	27000	45000	31500	0	2500	9000	0	2500	0	0
		(*)	(2)			(2)	(1)	(2)		(1)	(1)		(1)		
	Total for the region	(*)	7184 (28)	2093 (9)	0	4994 (24)	5992 (11)	5390 (16)	465 (2)	1097 (16)	3256 (5)	513 (3)	872 (10)	1560 (2)	0

(*) - Number of surveyed growers who answer this question

5.3.4.2 - Cultivars

The most popular cultivars amongst growers (question no. 3) listed in Table 5.9, are almost the same in both regions, with the exception of tomato, where Carmello is the most frequent cultivar in the Algarve while Dombito and Dombello are the predominant cultivars in the West. Nisen *et*

al.(1988) refer to Carmello as the tomato cultivar preferred by growers suffering from salinity problems in the Mediterranean conditions. This could well be the reason why the growers in the Algarve are happy with the performance of this cultivar. In consequence, they have been producing it in the last 4-5 years in spite of the fact that this cultivar, under cold conditions, produces lower amounts of pollen and the pollen is of poor quality, according to the same authors. In the West, Carmello is used as a spring cultivar.

Table 5.9 - Most important cultivars grown in the Algarve and in the West

	PRESENT SURVEY		Zettelmeyer & Henriques (1986)(**)
	WEST	ALGARVE	ALGARVE
TOMATO	Dombito (13)(*) Dombello (10) Dombo (8) Buffalo (8) Carmello (6) Bermuda (5)	Carmello (25)(*) Dombo (9) Bermuda (7) Marca (6) Dombito (5)	Carmello Ultra boy Dombito Monte Carlo Floritalia Marca
MELON	Galia (2) Harvest King (2)	Galia (20) Harvest king (9) Mila (8) Galicum (5)	Galia Harvest King Macdimon
GREEN BEANS	Kwintus (12) Bonex (4)	Kwintus (22) Selka (15) Helda (4)	Selka Kwintus
SWEET PEPPER	Lamuyo (2)	Lamuyo (15) Gedeon (5)	Lamuyo Hybrid Pepper
CUCUMBER		Victory (11) Jazzer (3)	Victory

(*) - Number of surveyed growers with this cultivar
(**) - The cultivars are ordered according to the area sown with each one

Growers like to assay the most recent cultivars available on the market and they grew several cultivars each time they produce a crop. On average, each grower has 2.8 cultivars of tomato in both the regions surveyed in this study, 1.8 cultivars of green beans and 1.5 cultivars of melon in the West; in the Algarve these values are 1.9 cultivars for green beans and 1.7 cultivars for melon. However, in the last 4-5 years the most important cultivars have remained the same, reflecting the growers preferences, the market acceptability and the availability of seeds, since the grower relies almost exclusively on imported seeds for these hybrid cultivars.

5.3.4.3 - Seedlings

In both regions, the majority of growers produce their own seedlings (30 growers in the West and 23 in the Algarve) (question no. 18). However, at the moment it seems that in the West the growers only buy transplants as a solution for an unexpected situation (not enough plants for the available area; sudden disease outbreak on the nursery with subsequent destruction of many transplants); by contrast in the Algarve a small number of growers with better technical facilities are simultaneously running greenhouse production units and commercial nurseries, which are providing the market with the necessary transplants for existing demand, mainly tomato and melon.

5.3.4.4 - Yields

The yield levels obtained by the growers (question no. 3) are normal values for Mediterranean standards (Table 5.10). The average yiels levels indicated by growers in the West are, in general, higher than the values from the Algarve (Table 5.10), but significant differences ($p.< 0.05$) were only found for the tomato and green bean crops. Cultural practices followed by the growers in both regions present in some cases differences too, as discussed in next sections (5.3.4.5 - 5.3.4.8), which could in some way explain the variation in yields.

5.3.4.5 - Manure

Manure is applied almost every year to the soil, either once (always before the tomato crop) or twice (before every crop), presenting the same pattern of manure distribution in both areas (only two growers in the Algarve reported manure application every two years) ($X^2_{[1]} = 0.175$ (n.s.)). When growers indicated the manure amounts employed in volumetric terms, a weight/volume relation of 0.3 t m^{-3} was used to convert data (Zettelmeyer & Henriques, 1986).

The average amount of manure, mainly cattle manure, applied in the West is not significantly greater than in the Algarve (Table 5.11), which could be expected by the occurrence of a higher proportion of sandy soils and the

Table 5.10 - Average yield levels (kg m^{-2}) claimed by the growers in both regions compared with other data from the Mediterranean area

Region	Class of area (ha)	Crops	TOMATO	MELON	GREEN BEANS	LETTUCE	SWEET PEPPER	CUCUMBER	STRAWBERRIES
WEST	≤1		10.7 (17) (*)	6.0 (3)	3.5 (12)	3.2 (4)		21.2 (4)	
	>1-5		10.4 (7)	7.5 (1)	4.4 (4)		8.5 (1)	15 (1)	3.0 (1)
	Total for the region		10.7 (24)	6.4 (4)	3.7 (16)	3.2 (4)	8.5 (1)	20 (5)	3.0 (1)
ALGARVE	≤1		7.6 (6)	5.0 (5)	1.5 (3)		4.8 (5)	9 (2)	
	>1-5		9.7 (4)	3.2 (3)	2.4 (3)		4.8 (2)		
	>5-10		7.5 (2)	3.0 (1)	1.8 (2)		3.5 (1)		
	Total for the region		8.3 (12)	4.2 (9)	1.9 (8)		4.6 (8)	9.0 (2)	

(*) - Number of surveyed growers who answer this question

ALGARVE (Zettelmeyer & Henriques, 1986)	8.4 (298) (**)	5.6 (179)	2.2 (158)	6.0 (18)	5.6 (85)	9.6 (86)	4.8 (2)

(**) - Number of studied cases

ALMERIA (SPAIN) (Steane, 1985)	8 - 10			5	4.5 - 6	8 - 11	
THE MEDITERRANEAN AREA (Nisen et al., 1988)	7 - 10 south 10 - 15 north	6 - 7	1.5 - 2 winter 2 - 4 spring	3 - 4	average yield depends on the crop cycle length	10 - 15 winter 18 - 25 spring	2 - 4

existence of manure sources closer to the greenhouses in the West than in the Algarve. In the Algarve growers are increasingly facing difficulties getting the amounts of manure they used to apply.

Table 5.11 - Amounts of manure applied in the surveyed areas (average values in t ha^{-1} for each group and for the region)

	Before each crop (twice an year)	once an year	once every two years	REGION
WEST	26.5	73.2		48.3
(*)	(16)	(14)		(30)
ALGARVE	40.5	27.0	52.5	37.8
(*)	(10)	(12)	(2)	(25)[a]

(*) - Number of surveyed growers who answer this question

(a) - One grower in the Algarve indicated the manure amount but did not specify when he applied it

Furthermore the cost of manure represents, on average, about 20% of the direct costs of the crops, according to data collected by Zettelmeyer & Henriques (1986) in this area. Those reasons, along with the fact that many greenhouses already have a reasonable level of organic matter in the soil, could induce a reduction in the amounts of manure applied in the near future. Nevertheless, one grower surveyed in this area is still applying 100 t ha^{-1} before each crop.

5.3.4.6 - Fertilisers

Fertilisers are applied in two distinct ways: i) in a pre-planting distribution and ii) during the growing period, mainly as a nutrient solution through the irrigation system ("liquid feeding") (30 growers in the West and 26 in the Algarve use "liquid feeding" while 2 growers in the West and 3 in the Algarve do not use this system).

The most frequently used pre-planting fertilisers are the same in both areas, "Foskamonio 133" (7% N; 21% P_2O_5; 21% K_2O) and "Superphosphate 18" (18% P_2O_5) but the predominant top-dressing fertilisers differ between the areas (Table 5.12).

Table 5.12 - Major fertilisers used by the growers and their content in macronutrients

	PRE-PLANTING				TOP-DRESSING (‡‡)			
	Fertilisers	% macronutrients N	P_2O_5	K_2O	Fertilisers	% macronutrients N	P_2O_5	K_2O
W	Foskamonio 133 (6)(‡)	7	21	21	Calcium nitrate (17)(‡)	15.5	0	0
R	Superphosphate 18 (6)	0	18	0	Potassium nitrate (16)	13	0	0
S	Magnesium sulphate (3)	0	0	0	Magnesium sulphate (12)	0	0	0
T					kristalon (5)	15	3	19
A	Foskamonio 133 (15)	7	21	21	Urea (11)	46	0	0
L	Superphosphate 18 (6)	0	18	0	Potassium nitrate (9)	13	0	46
G	Foskamonio 111 (6)	10	10	10	Kristalon (9)	15	3	19
A	Nitrofoska (4)	15	10	15	Nitrofoska (8)	15	10	15
R	Foskapa 022 (4)	0	21	21	Ammoniun sulphate (4)	20.5	0	0
V	Blaukorn (3)	12	12	17	Nitrolusal (3)	23.3	0	0
E					Potassium sulphate (3)	0	0	50

(‡) - Number of the surveyed growers who indicated this fertiliser
(‡‡) - Mainly supplied as "liquid feeding"

Fertiliser applications are empirically made in the Algarve by the majority of the growers (22 out of 29), while in the West the growers try to use fertilisers according to the results of a recent soil analysis (25 growers out of 32). This is, possibly, one of the major differences between the regions, since in the Algarve the growers apply fertilisers (types and amounts) based on their own experience and guesses while in the West the growers try to adapt the fertiliser use to the plant needs in accordance with the nutrient status of the soil.

However, when these results were compared with the yield obtained by the growers, with and without soil analysis, in the Algarve, the average yields for the growers who used the soil analysis technique were 8.4 kg m^{-2} for tomato, 4.2 kg m^{-2} for melon, 1.6 kg m^{-2} for green beans and 3.8 kg m^{-2} for sweet pepper. By contrast, the average values for the growers who did not take a recent soil analysis were 8.2 kg m^{-2} for tomato, 4.2 kg m^{-2} for melon, 2.2 kg m^{-2} for green beans and 5.1 kg m^{-2} for sweet pepper, suggesting that, in the Algarve, growers who make fertiliser application based on soil analysis information are not performing better than the growers who do not use this information.

5.3.4.7 - Irrigation

Irrigation in the Algarve is made predominantly through perforated hoses, as stated in Chapter 3, and in the West

growers generally use drip irrigation systems. This difference in the irrigation systems and the different predominant soil types in the areas induces a distinct irrigation behaviour in each area under hot weather conditions (Fig. 5.10). In the West the majority of the growers irrigate every day and, on average, apply a nutrient solution through the irrigation system every 3-4 days (Table 5.13) while in the Algarve the growers irrigate twice or once a week and add the nutrient solution every other or every two irrigation periods (Table 5.13).

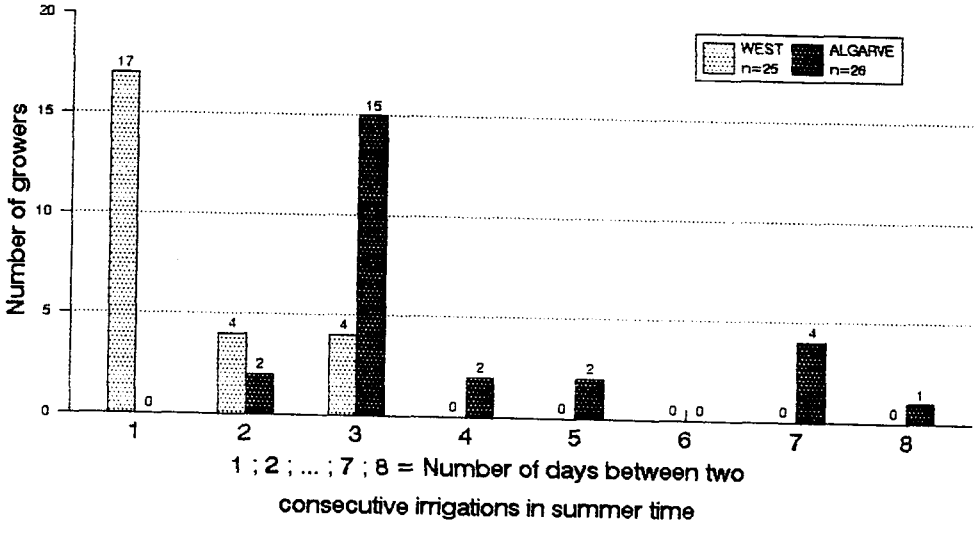


Fig. 5.10 - Distribution of the irrigation periods in both of the surveyed areas

5.3.4.8 - Plant management in tomato, melon and sweet pepper crops

All the growers normally cut the axillary shoots of **tomato** along the main stem. They also cut out the leaves of the lower part of the plant in order to increase the ripening

Table 5.13 - Average top-dressing intervals (in days) in both areas

TOP-DRESSING INTERVAL (DAYS)	WEST	ALGARVE
≤ 7	3	6
(*)	(26)	(6)
>7	45	14
(*)	(1)	(17)
Average for the region (*)	4	12
	(27)	(23)

(*) - Number of the surveyed growers who indicated this interval

of the fruit and the ventilation in the lower part of the plant. However, a great number of growers use to cut the petioles and the axillary shoots several cm's away from the stem, leaving along it sometimes quite long stumps. In the West all the growers stopped the plant by removing the main stem apice of the tomato plant when it reaches 6 - 8 clusters, while in the Algarve 55% (16/29) of the surveyed growers do not pinch out the tip of the plant.

Considering the answers to this question from the Algarve and plotting them against i) the size class of area, ii) the number of years the growers have been growing vegetables in greenhouses and iii) the yield obtained, indicated that there are no significant differences between the two groups of growers (pinch out the tip of the plant *versus* do not pinch out the tip) ($X^2_{[2]}$= = 0.09 (n.s.) for the size classes, and average values of 9 years producing

vegetables in greenhouses and 8.3 kg m^{-2} for the growers who pinch out the tip of the tomato plant while the average values for the growers who do not pinch out the tip of the plant are 8.6 years and 8.2 kg m^{-2} respectively).

In the Algarve the majority of the growers (72 %) apply plant growth regulators on tomato (auxin-type hormones) during the winter and early spring (cold and wet weather conditions) while in the West this technique is either almost unknown or, if known, not applied (only one grower reported its application and a few of them asked several questions about this technique during the interviewing; it is worth mentioning the fact that the grower who applied growth regulators in the West noticed an increase in grey mould attacks on the crop). Zettelmeyer & Henriques (1986) indicate exactly the same percentage of growers applying plant growth regulators on tomato in the results of the survey done in the Algarve four years ago covering a much bigger number of growers.

Since the Carmello cultivar has been the predominant tomato cultivar used by the growers in the Algarve for the last few years, the use of plant growth regulators by the growers could be regarded as a way to improve the performance of the Carmello cultivar in winter time, when this cultivar produces small amounts of pollen.

On **melon** the pruning system used in the Algarve was the only plant management technique assessed through the

questionnaire for this crop and it shows that the growers have a diversified opinion about the system to use: 14 growers prefer not to cut the main stem of the plant leaving it with one main axis; 7 growers prefer to cut the main stem and use two secondary shoots to get a plant with two main axes; finally 6 growers prefer to cut the main stem leaving one secondary shoot to be trained as the main axis, out of the 27 growers who answered this question.

Clearly the growers have reasons for such a diversification of opinions about this technique since as Nisen *et al.* (1988) stated for the Mediterranean conditions ..." *the choice of a pruning system depends on the planting distance, cultivar, environment, etc.; therefore it is impossible to say which pruning system is the best for whatever conditions* ". The cutting of the main stem and subsequent training of the plant with two main axes is indicated by Marreiros (1987) for the cultivar Galia (the most used in the Algarve region) in a technical leaflet distributed by the extension services throughout the Algarve, allowing the conclusion that this is the recommended technique for the area. Nevertheless, the data collected through the survey suggest that the growers using the first described pruning system (do not cut the main stem of the plant) get better yields (6.6 kg m^{-2} on average) than the growers who cut the main stem and use two main axes (2.9 kg m^{-2} on average) or use one main axis (3.2 kg m^{-2} on average). The latter pruning system seems to be used by growers coming later to the greenhouse activity

since the growers using this technique have been producing vegetables in greenhouses for 5.5 years on average while the growers using the first and second described techniques have been growing on average 9.9 years and 9.6 years, respectively.

For the **sweet pepper** crop the only data collected in this survey concerning plant management is related to the removing of the leaves and pruning, again for the Algarve. The growers have a divided opinion about this technique, with 9 growers removing the leaves and cutting the axillary shoots below the first branching of the plants and 6 growers who just leave the plant to grow without pruning (out of the 15 growers who gave information about this question). The distribution of these growers per size class showed that the 6 growers not using pruning techniques belong to the size class $\leq$ 1 ha, while the growers belonging to the larger size classes use pruning techniques (Fisher exact test (p. = 0.017)). On the other hand the growers who remove the leaves and cut the axillary shoots have been producing vegetables in greenhouses for 9.7 years on average and get an average yield of 3.6 kg m^{-2} while the growers in the other group have been producing for 8.4 years and obtain 6.5 kg m^{-2} on average.

Nisen *et al.* (1988) stated that under Mediterranean conditions ..."*it is rarely necessary to control the growth of the plant by pruning operations...*" inside the greenhouses unless attacks of *Botrytis cinerea* are very important, in which case the pruning of the plant would

increase the ventilation, reducing the risk of the disease. These authors also point out that the leaves of the sweet pepper plant have a rather low efficiency in photosynthetic terms which justify the need for a reasonable amount of leaves on the crop. The grey mould disease is rarely regarded by the growers as a major one on this crop in either region, as indicated in Chapter 5.3.6.2, and the data collected during this survey suggest that this technique is not improving the results obtained by the growers.

5.3.4.9 - Growers' attitudes towards future crops

The attitude of the growers about the number of crops they are planning to grow in the future is also different in the two regions (question no. 5). In the West, half the surveyed growers wish to increase the number of crops in the future, while in the Algarve the majority of the growers plan to maintain the number they grow now (Fig. 5.11).

The growers planning to increase the number of crops are the most recent in the industry (the average number of years they have been producing vegetables in greenhouses is 2.3 years in the West and 5.8 years in the Algarve) while the growers planning to maintain the number of different crops have been in the industry for a longer period (on average 5.6 years in the West and 9.5 years in

the Algarve). One grower in the West area, who did not know yet what to do, has been producing vegetables in greenhouses for 3 years, which fits well the behavioural pattern described above. However, the growers in the Algarve planning to reduce the number of crops have been in this activity for 7.5 years on average, and the reasons for their decision must be based on different causes.

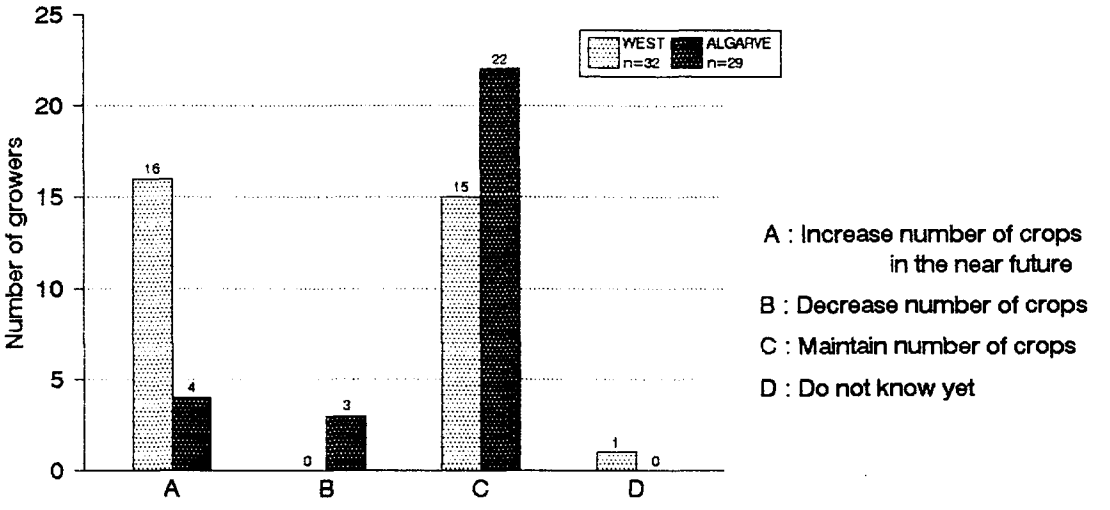


Fig. 5.11 - Attitude of the growers to the number of crops they plan to grow in the near future

5.3.4.10 - Crop sequences

The crop sequence (question no. 4) followed by the growers reflects the interaction of several distinct factors linked with the profitability of the different crops, the agronomical need to rotate the crops inside greenhouses,

the knowledge and expertise of the grower about the different crops and the relation of the grower to the market (growers contracted to produce a particular crop(s) for a market agent (supermarket, cooperative, export company) *versus* growers who sell without contracts (growers either try to anticipate the market situation during the next season or they react to the best prices of the last season)). As a consequence the crop sequence can vary considerably between growers in one region, and for the same grower over a few years.

Nevertheless, at present, the crop sequences tomato / green beans or tomato / green beans-tomato seem to be prevalent in the West region while in the Algarve the crop sequences tomato / melon, tomato / green beans or tomato / melon--green beans seem to be quite common (Table 5.14). There is great variation among the crop sequences for the other crops and normally they occupy smaller areas, as indicated in Table 5.8. Finally it should be noted that two consecutive tomato crops are frequently produced in the same place by growers in both regions.

5.3.5 - The grower

In order to characterise the grower three parameters were assessed during the interview, related to his educational background (question no. 43), his experience in this agricultural activity (question no. 1) and his age (question no. 42).

Table 5.14 - The crop sequence: number of cases that the crop indicated on the row is produced after the crop indicated on the column, in both regions.

\ REGION / NEXT \ CROP \		PREVIOUS CROP							
		TOMATO	MELON	GREEN BEANS	CUCUMBER	LETTUCE	SWEET PEPPER	STRAWBERRIES	AUBERGINES
TOMATO	W	6	5	20	4	4	1	2	
	A	6	17	11	5	2	7		
MELON	W	3		3	1	1			
	A	18		9	3		6		1
GREEN BEANS	W	27	1			1	1		
	A	15	11		3		2		
CUCUMB.	W	2		3		1	1		
	A	3	2	3			2		
LETTUCE	W	2		2	1				
	A	1		1			1		
SWEET PEPPER	W	1	2		1				
	A	7	1	7	1				
STRAWB.	W	1		1					
	A								
AUBERG.	W								
	A	1							

The majority of the growers in the Algarve completed primary school (Fig. 5.12). In the West the number of growers with a primary school background is slightly greater than the number of growers who have either partial or complete studies on a secondary school, and 13% of the

surveyed growers (4 out of 32) have a higher degree in agriculture, while in the Algarve only 6% of the surveyed growers (2 out of 29) have this educational background.

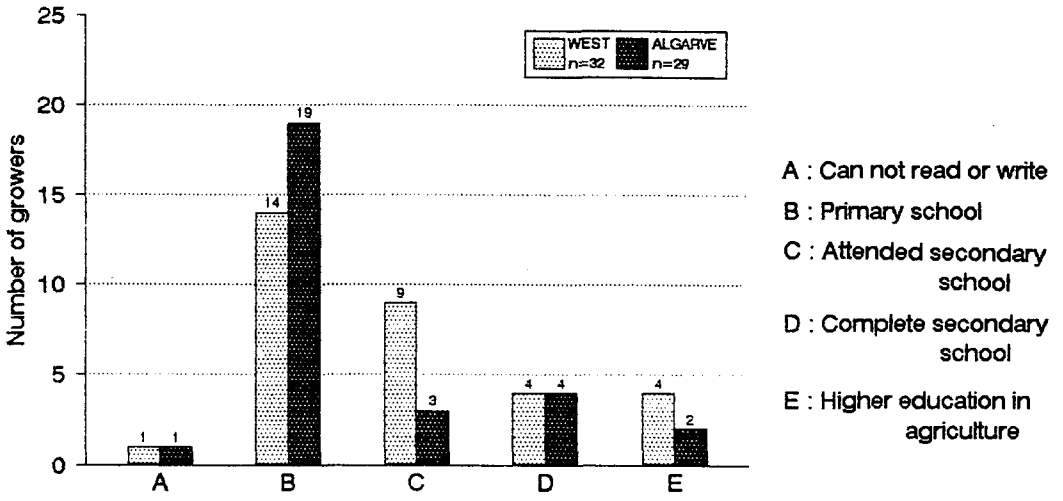


Fig. 5.12 - Educational background of the growers in both of the surveyed regions

It is interesting to note that one grower in each area can not read or write and both have been growing vegetables in greenhouses for 10 years. Bearing in mind the amount of technical information needed by a grower to support the profitable management of this agricultural system, the success of these two growers must rely on their horticultural skills and the accumulated expertise during the last ten years, since each of them has an area of greenhouses between 1 ha and 5 ha. The need for technical information could be the explanation why, in a region of the country where the illiteracy rate is higher than the national average, like the Lourinhã municipality (Cabral,

1987), the number of illiterate growers running greenhouses is so small.

The distribution of the growers according to the number of years they have been producing vegetables (Fig. 5.13) agrees entirely with the historical development of the industry in both areas, as discussed in Chapter 3.1. In the West this activity developed first in the Torres Vedras area (4.5 years on average) and spread fast along the coast to the northern areas of the region (Lourinhã 3.6 years on average, Peniche 1.5 years on average) (see Fig. 5.1).

In the Algarve the grower with most years in this activity has been producing for 25 years and is located in the Eastern part of the region (Vila Real de S. Antonio) (see Fig. 5.2), while the average number of years in the industry is 8.7 years for the growers in the area of Faro and 8.3 years for the growers from the Tavira area. The average number of years for the growers from the Silves area is 3.8, which shows the later development of the industry in the western area of the Algarve.

The most recent growers in this activity, in the West belong to the age class >30 - 40 years old (on average 2.8 years in the industry); the growers belonging to the age class >20 - 30 years old have been in the industry for 3.8 years on average and the growers of the age class >40 - 50 years old have been for 5.1 years on average. One grower in the age class >50 - 60 has been in the industry for 2

years. By contrast, in the Algarve growers in the age class >20 - 30 have been in the industry for 3.5 years on average, for the age class >30 - 40 the average is 7.3 years, for the age class >40 - 50 the average is 9.6 years, for the age class >50 - 60 the average is 12.3 years, and for the age class >60 the average is 14.0 years.

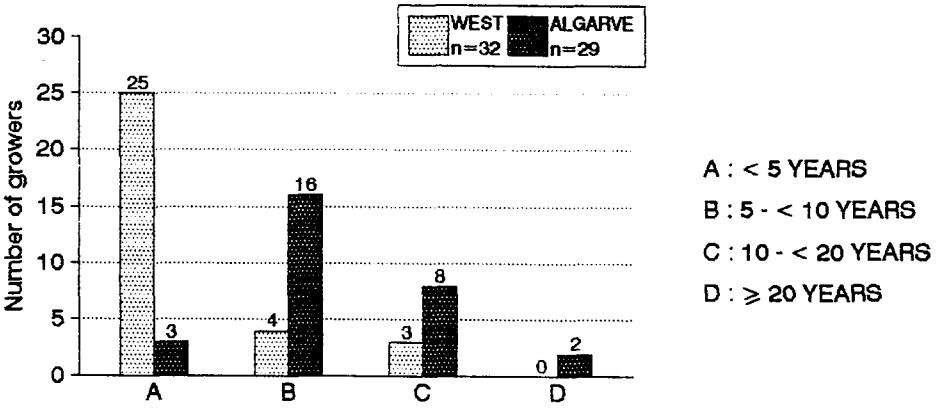


Fig. 5.13 - Distribution of the growers according to the number of years they have been producing vegetables in greenhouses

The survey data gives some evidence that in the West the greenhouse industry has been considered a real alternative agricultural system by the young growers and, not surprisingly, the average age of the surveyed growers was lower in the West than in the Algarve (respectively 34 years old and 42 years old) (Fig. 5.14). Such a difference could explain the variation in the educational background of the growers in both regions, previously discussed, and could be the reason why in the Algarve there is a positive

correlation between the age of the growers and the number of years they have been in the industry (r = 0.65 with a level of significance = 0.0001), while in the West such correlation was not found (r = 0.09 with a level of significance = 0.61).

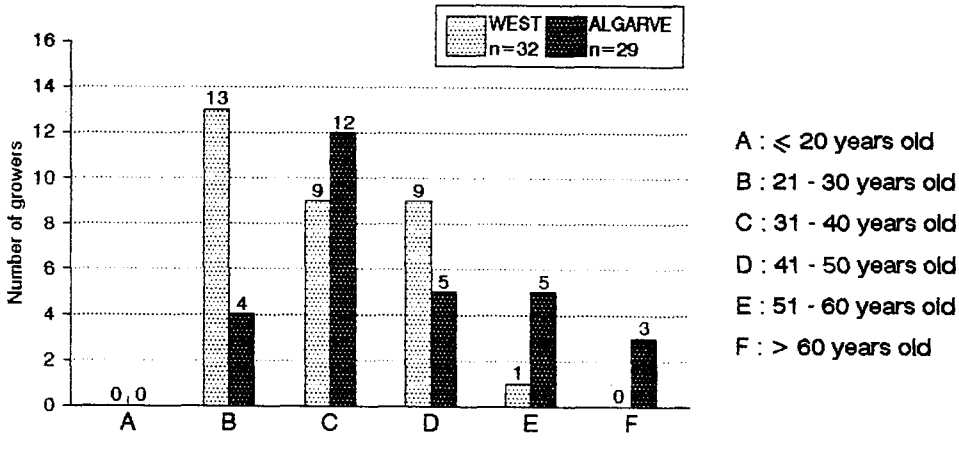


Fig. 5.14 - Distribution of the surveyed growers per classes of age

5.3.6 - Pest problems perceived by growers and control methods

The second section of the questionnaire deals with the pest problems faced by the growers and the measures adopted for their control.

5.3.6.1 - Weeds

When the growers were asked which crops had more weed problems (question no. 11-a) they almost always indicated

their major crops (all the growers indicated tomato in the first place in both regions while the second crop was melon (24 growers), green beans (3 growers) and sweet pepper (1 grower) in the Algarve and in the West they indicated green beans (24 growers) and lettuce (4 growers).

The weeds mentioned as the most troublesome or frequent/abundant (question no. 11-b) differed between regions and on average each grower referred to three different weeds (3.0 in the West and 3.4 in the Algarve). The most important weeds affecting the tomato crop (Fig. 5.15) were, in the West *Oxalis pes-caprae* L. (mentioned by 13 growers), *Solanum nigrum* L.(12 growers), *Chenopodium album* L. (10 growers), *Cyperus* spp. (10 growers), *Digitaria sanguinalis* (L.) Scop. (7 growers) and *Cynodon dactylon* (L.C.Rich) Pers. (5 growers). In the Algarve the most common weeds were *Galium aparine* L. (19 growers), *Amaranthus retroflexus* L. (18 growers), *Oxalis pes-caprae* L. (9 growers), *Cyperus* spp. (7 growers), *Digitaria sanguinalis* (L.) Scop. (7 growers), *Malvaceae* (*Lavatera* spp./*Malva* spp.) (7 growers), *Convolvulus arvensis* L. (6 growers) and *Hordeum murinum* L. (5 growers).

It is worth mentioning that two growers in the Algarve pointed out *Orobanche* spp. as a troublesome weed in the tomato crop. This problem is particularly worrying since these root obligate-parasitic weeds have a tremendous biological potential to spread themselves (each plant can produce up to 100,000 tiny dustlike seeds which are dispersed by wind and water and can remain viable in the

soil for a long time, allowing the attack of these weeds to a wide range of hosts) (Bischof, 1978; Kasasian, 1971; Lolas, 1986).

In the eastern Mediterranean and middle east countries several *Orobanche* spp. have been reported attacking many vegetable crops causing considerable losses (Kasasian, 1971; Lolas, 1986; Musselman, 1980, 1982; Saghir, 1986). In California *Orobanche ramosa* L. has been considered responsible for 20% to 30% yield reductions in tomato (Cordas, 1973). This species is particularly troublesome since it can attack potato, tobacco, melon, sunflower, safflower, lettuce, maize, carrot, brassicas as well as tomato (Kasasian, 1971) and is present in all the Mediterranean area, France, England and Germany (Holm *et al.*, 1979). Other important *Orobanche* species in the eastern Mediterranean area affecting *Solanaceae* crops and particularly tomato are *O. aegyptiaca* Pers. and *O. cernua* Loefl. (Musselman, 1980; Holm *et al.*, 1979).

In spite of the fact that of these three species only *O. ramosa* is reported as occurring in Portugal, (at least two subspecies *O. ramosa* subsp. *mutelii* (F.W.Schultz) Coutinho and *O. ramosa* subsp. *nana* (Reuter) Coutinho) (Chater & Webb, 1972), the identification of the species involved and the real dimension of this problem should be studied in order to determine the control methods to be employed to reduce the expansion of this weed problem.

Bischof (1978) indicated regular hoeing and weeding as an

effective control method. However, Jacobsohn *et al.* (1988) present some doubts about the efficacy of the hand-weeding technique in reducing the infestation levels of broomrape (*Orobanche* spp.). Other control methods which seem to be regarded as very effective for broomrape control are soil sterilisation with methyl bromide or alternatively soil solarization (Musselman, 1980 ; Jacobsohn *et al.*, 1988). Since all these techniques are used or can be used by growers in the Algarve, relevant information about the importance of achieving accurate control against these weeds should be provided to the growers.

The major weeds indicated above reflect the species with better capabilities to adapt themselves to the greenhouse environment, either through very efficient vegetative multiplication (*Oxalis pes-caprae, Cyperus* spp. (particularly *C. rotundus* L.), *Convolvulus arvensis, Cynodon dactylon*) or through highly productive sexual reproduction (*Solanum nigrum, Chenopodium album, Amaranthus retroflexus*), linked with advantageous competitive mechanisms (high photosynthetic efficiency, fast seedling growth, short life-cycle).

Oxalis pes-caprae is an abundant weed in the West in vineyards and orchards, which are two of the most common crops in the region. In the Algarve this species is frequent in the citrus orchards too and this could explain why this weed is a common species inside greenhouses in both regions. The same reason applies for *Cyperus* spp., *Cynodon dactylon* and *Convolvulus arvensis*.

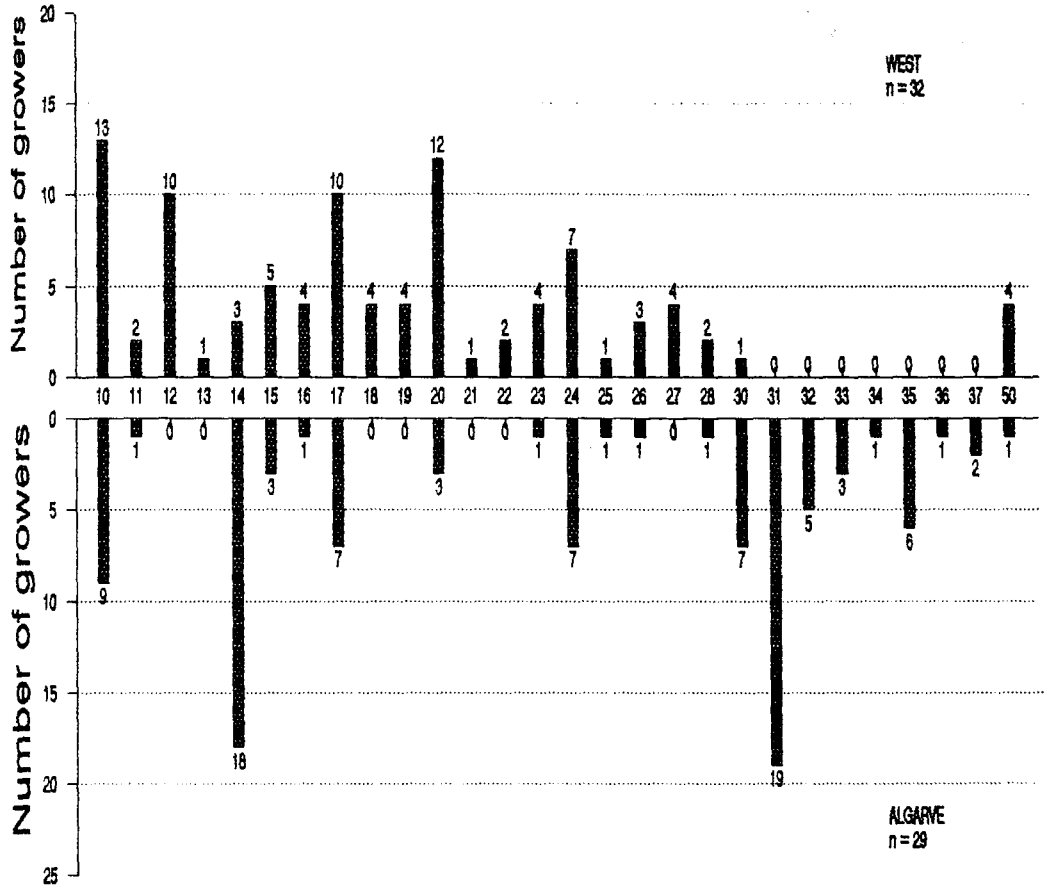
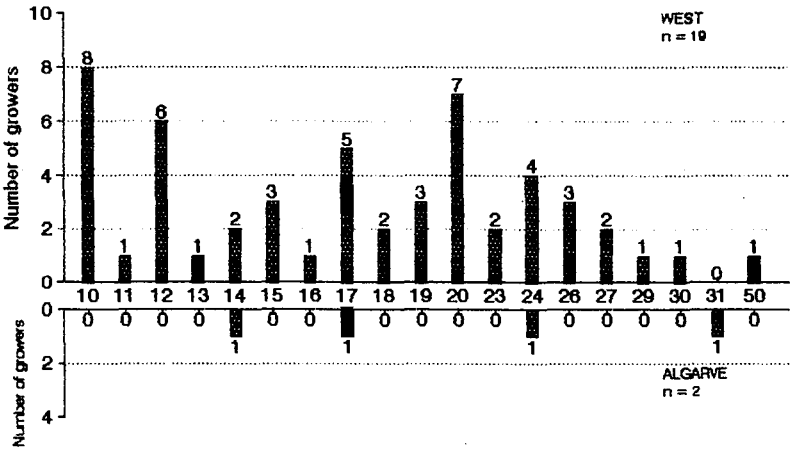


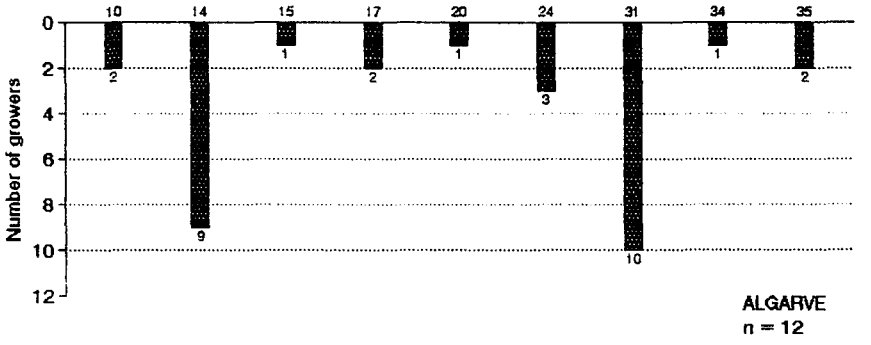
Fig. 5.15 - Weeds indicated by the surveyed growers for the tomato crop

10 - *Oxalis pes-caprae* L.
11 - *Avena* spp.
12 - *Chenopodium album* L.
13 - *Phalaris minor* Retz.
14 - *Amaranthus retroflexus* L.
15 - *Cynodon dactylon* (L.C.Rich) Pers.
16 - *Panicum repens* L.
17 - *Cyperus* spp.
18 - *Lolium* spp.
19 - *Rumex* spp.
20 - *Solanum nigrum* L.
21 - *Equisetum* spp.
22 - *Poa annua* L.
23 - *Portulaca oleraceae* L.
24 - *Digitaria sanguinalis* (L.) Scop.
25 - *Urtica* spp.
26 - *Sonchus* spp.
27 - *Raphanus raphanistrum* L.
28 - *Chrysanthemum* spp.
29 - *Polygonum aviculare* L.
30 - *Malva* spp./*Lavatera* spp.
31 - *Galium aparine* L.
32 - *Hordeum murinum* L.
33 - *Datura stramonium* L.
34 - *Medicago* spp.
35 - *Convolvulus arvensis* L.
36 - *Picris echioides* L.
37 - *Orobanche* spp.
50 - Several *Gramineae*

GREEN BEANS



MELON



LETTUCE

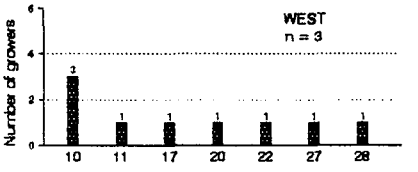


Fig. 5.16 - Weeds indicated by the surveyed growers for green bean, melon and lettuce crops

(The weed reference is made according to the legend of Fig. 5.15)

Solanum nigrum is a weed with environmental needs similar to those required by the tomato crop (Maillet & Abdel--Fatah, 1983). It can produce up to 10,000 seeds per plant and each seed can remain dormant for many years in the soil (Weller & Phipps, 1978). These authors also indicate that seeds can survive passage through the digestive system of animals which allows the dissemination of seeds in manure applied inside greenhouses. This contamination mechanism, and the germination of seeds over a considerable period of time (Weller & Phipps, 1978), certainly allows some black nightshade (*S. nigrum*) plants to escape the weeding effort and restore the seed bank in the soil.

Manure was also pointed out as the major source for the seeds of the weeds *Galium aparine* and *Amaranthus retroflexus* by the growers in the Algarve. *Galium aparine* is a common weed in cereal crops in the western Mediterranean countries (Montegut, 1974; Guillerm & Maillet, 1982) and since the growers in the Algarve bought the manure they apply mainly in the Alentejo districts, a major cereal growing area, this could explain the origin of this weed. In contrast *Amaranthus retroflexus* was already mentioned as a major weed in the Algarve greenhouses by Guerreiro (1979).

For the other crops the weeds pointed out by the growers were the same already indicated for the tomato crop (Fig. 5.16), with the single exception of *Polygonum aviculare* L. indicated by one grower in the West area occurring in the green bean crop. This suggests that those weeds are

either the species of the local flora or species repeatedly inoculated in the soil which are able to get advantages from the intensive production cycle and crop sequence inside greenhouses and are perceived and remembered by the growers as major weeds.

The **tomato** crop can be severely affected by weeds: weed densities greater than 10 plants m^{-2} can induce yield losses greater than 40% (Maillet & Abdel-Fatah, 1983). Some particular species indicated by the growers are amongst the most troublesome weeds on this crop: a) 1 plant of *Amaranthus retroflexus* m^{-2} can reduce yield by about 25% and 6 plants m^{-2} can cause a decrease of 73% in direct--seeded field tomatoes (Lange *et al.*, 1986), competition being mainly for moisture (Mohammed, 1978); b) less than 20 plants of *Solanum nigrum* m^{-1} of tomato row causes a yield loss of about 50% in transplanted tomatoes (Maillet & Abdel-Fatah, 1983) reporting Damato & Montemurro (1986) that under field conditions, black nightshade densities greater than 1 plant m^{-2} significantly reduced tomato yield; c) high densities of *Cyperus rotundus* (greater than 400 plants m^{-2}) can cause a yield reduction up to 53% on tomato if the weeds are present during the entire crop season, competition being mainly for light and nutrients (William & Warren, 1975; Keeley, 1987).

Beans are generally considered more tolerant to weed competition owing to the fast growth of the crop. In spite of that the necessity of weeding the crop during the first third of the crop season is widely recognised (Zimdahl,

1980). In some field conditions with high infestation levels of *Cyperus rotundus* (>400 plants m^{-2}) yield losses varied between about 40% and 80% (Keeley, 1987).

Lettuce is particularly sensitive to weed competition, specially during the first three weeks after emergence of the crop (Zimdahl, 1980; Appezzato *et al.*, 1983). According to Zimdahl (1980) weed densities greater than 60 plants m^{-2} cause total or nearly complete yield loss, competition being mainly for light.

Sweet pepper yield can be severely reduced by weed competition and, under field conditions, the critical period of weed interference in this crop seems to be from 20 to 40 days after transplanting (Labrada & Paredes, 1983).

Since, as Tisdell *et al.* (1984) stated ..." *the higher the price received for the produce, ..., the lower the (weed) density at which treatment is economic*" and as the price of greenhouse vegetables is usually higher than the price of field vegetables, it is easy to assume that inside greenhouses weed densities justifying control methods should be lower than in the open.

5.3.6.2 - Diseases and arthropod pests

Question no. 10 was intended to clarify which pest problems the growers faced in their crops and this question should

be regarded together with questions no. 14-a and 14-j to identify which of the indicated problems are the most important from the growers point of view.

For the tomato crop every single grower in both regions covered by the survey answered question no. 10 and the predominant pest problems in the West are grey mould (29 growers), caterpillars (29 growers), late blight (22 growers), whiteflies (19 growers), nematodes (16 growers), powdery mildew (15 growers) and leafminers (10 growers) (Fig. 5.17); for the Algarve the predominant problems are grey mould (27 growers), late blight (23 growers), nematodes (22 growers), whiteflies (21 growers), aphids (21 growers), caterpillars (21 growers), spider mites (19 growers) and powdery mildew (11 growers) (Fig. 5.17).

Whiteflies are essentially regarded as a summer pest in the West while in the Algarve, accordingly to the growers' opinion, this pest appears early, mainly in the spring and their presence continues throughout the summer (Tables 5.15 and 5.16).

Spider mites in the Algarve were reported as being more abundant in late spring, with hot weather, but their attacks can begin as early in the season as February. Their attacks seem to be concentrated around the central poles supporting the greenhouse structure, suggesting that the mites get protection under the bark and inside crevices along the wooden poles, during the unfavourable period. Aphids, on the contrary, are reported to be present on the

crop in early spring, during March-April, in the Algarve (Tables 5.15 and 5.16).

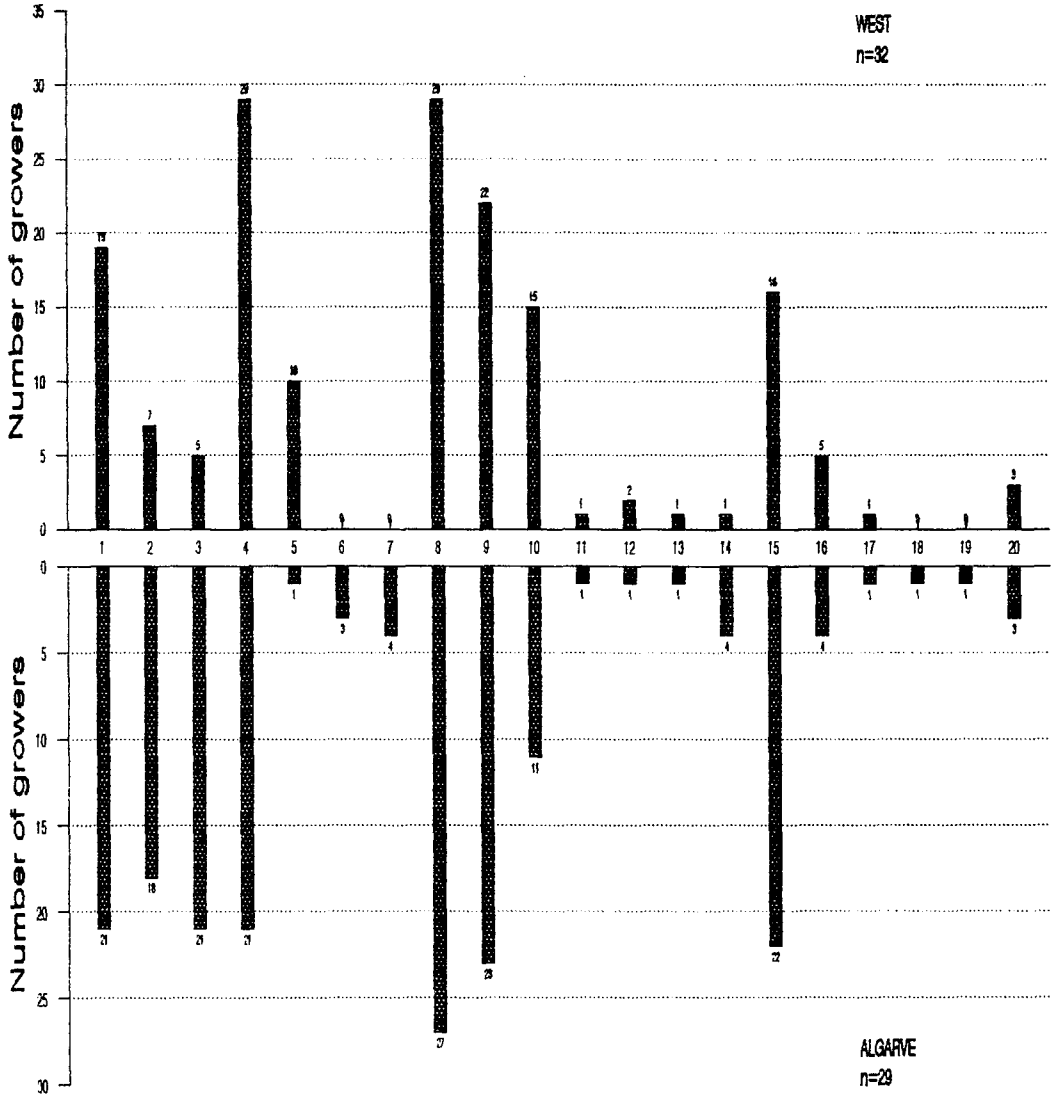


Fig. 5.17 - Pest(*) problems and physiological disorders indicated by the surveyed growers for the tomato crop.

1 - Whiteflies
2 - Spider mites
3 - Aphids
4 - Caterpillars
5 - Leafminers
6 - Russet mites
7 - Soil insect pests
8 - Grey mould
9 - Late blight
10 - Powdery mildew
11 - Cladosporiose
12 - Corky root rot
13 - Wilting
14 - *Fusarium* spp.
15 - Nematodes
16 - Bacteria
17 - Viruses
18 - Tomato "Mal azul" (mycoplasma)
19 - Rats
20 - Blossom end rot (physiological disorder)

(*) - Pest is used here in its broadest sense, as indicated in Fig. 2.1, with the exception of weeds since they were discussed in the previous section.

Caterpillars are essentially a pest problem in the summer--autumn crop in the West while in the Algarve the collected data suggests that these pests can affect all crops during the autumn-winter and spring periods (Tables 5.15 and 5.16).

Leafminers are only considered a regular problem in the West, in the beginning of the summer-autumn crop, immediately after transplanting (Table 5.15).

Grey mould and late blight are particularly feared in wet and cold weather conditions during autumn-winter in both regions; powdery mildew is essentially a problem on the summer-autumn crop in the West, and this pathogen appears early in the season (Tables 5.15 and 5.16).

When the growers were asked to indicate the most important pest problems on their main crops (question no. 14-a) all the surveyed growers pointed out tomato in the first place and grey mould and late blight were considered the two major problems on this crop (Table 5.17). The majority of the growers who pointed out grey mould (22 growers in the West out of 26 and 16 growers in the Algarve out of 25) considered that this pathogen causes problems every year (question no. 14-c), since the beginning of the crop. For those who indicated late blight, 12 growers (out of 17) in the West and 5 growers (out of 13) in the Algarve considered that this disease causes problems every year (question no. 14-c). It seems that in the Algarve both diseases are regarded by some growers more as a potential

Table 5.15 - Periods of occurrence for the major pest problems, on tomato in the West, according to the growers' perceptions.

time	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Fev	Mar	Apr	Mai	Jun	Jul	GROWERS' REMARKS
Cropping-cycle of the tomato crop in the West (*).		*...N...													
		*.....G.....						*....N....							
					*.....H.....				*.....G.....						
											*.....H.....				
GREY MOULD				...XXXXXXXXXXXXXXXXXXXXXXXXXXXX...											It causes troubles in humid weather. In summer time it is not a problem
LATE BLIGHT				...XXXXXXXXXXXXXXXXXXXXXXXXXXXX...											linked with: humid weather; rainy weather
POWDERY MILDEW			...XXXXXXXXXXXXXXXX...												
BACTERIA				...XXXXXXXXXXXX...											Before beginning harvest
NEMATODES			...XXXXXXXXXX...												Symptoms can begin 15 days after transplanting
WHITEFLIES	..XXXXXXXXXXXXXXXXXX...											...XXXXXXXXXXXXXXXXXX..			Early in the season; during hot weather; during fruit set
CATERPILLARS			...XXXXXXXXXXXXXXXX...												Egglaying on flowers or at fruit set; during hot weather; in early season imediately after whitefly
LEAFMINERS	...XXXXXXXXXXXXXXX...														In the beginning of the season; immediately after transplanting
APHIDS			...XXXXXXXXXX...												During hot weather
SPIDER MITES	..XXXXXXXXXX...											...XXXXXXXXXXXXXX..			During summer time; when temperature increases

(*) : N - nursery period; G - vegetative growing period; H - harvest period

Table 5.16 - Periods of occurrence for the major pest problems, on tomato in the Algarve, according to the growers' perceptions.

time	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Fev	Mar	Apr	Mai	Jun	Jul	GROWERS' REMARKS
Cropping-cycle of the tomato crop in the Algarve (*).			♯..N...			♯...N.....									
							\♯.....G.....								
			\♯.....G.....						\♯.....H.....						
						\♯.....H.....									
GREY MOULD					...XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX...										In the winter; Sometimes the first truss is completely lost
LATE BLIGHT						...XXXXXXXXXXXXXXXXXXXX...									In the winter
NEMATODES			...XXXXXXXXXXXXXX...								...XXXXXXXXXXXXXXXX...				
WHITEFLIES										...XXXXXXXXXXXXXXXXXXXXXXXX...					In spring-summer time; during hot weather
CATERPILLARS				...XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX...											All the year round; cutworms and caterpillars particularly important in crops sown late autumn
APHIDS								...XXXXXXXXXXXXXXXXX...							
SPIDER MITES									...XXXXXXXXXXXXXXXXXXXXXXXXX...						During summer time; when hot weather begin; attacks patched around greenhouse central poles
RUSSET MITES										...XXXXXXXXXXXX...					In hot weather

(*) : N - nursery period; G - vegetative growing period; H - harvest period

threat than as an actual problem. However, the heavy losses which can result from their attack make these pathogens the

worst pest problems perceived by the growers.

Nematodes and spider mites in the Algarve, and caterpillars in the West, were also regarded by some of the growers as major problems in the tomato crop inside greenhouses. In the Algarve nematodes are noticed, on average, after 4 years of crop production (4 growers out of 7) while in the West they seem to be noticed earlier, on average after 2 years of crop production (3 growers out of 4) (question no.

Table 5.17 - Most important pest problems on tomato according to the growers' perceptions

REGION	WEST	ALGARVE
WORST PEST PROBLEM	Grey mould (19)‡ Late blight (6) Powdery mildew (2) Nematodes (2) Bacteria (2) Whiteflies (1)	Grey mould (20) Nematodes (6) Late blight (2) Whiteflies (1)
--	--	--
‡‡	32	29
SECOND WORST PEST PROBLEM	Late blight (11) Grey mould (7) Caterpillars (5) Nematodes (2) *Fusarium* (1) Spider mites (1) Powdery mildew (1) Bacteria (1)	Late blight (11) Grey mould (5) Spider mites (5) Nematodes (1) Soil fungi (1) Caterpillars (1) Whiteflies (1) Tomato "Mal azul"(1)
--	--	--
‡‡	29	26
MAJOR ARTHROPOD PEST PROBLEM	Caterpillars (19) Whiteflies (1)	Caterpillars (9) Spider mites (7) Russet mites (2) Whiteflies (1)
--	--	--
‡‡	20	19

‡ - Number of growers indicating this pest
‡‡ - Number of growers answering this question

14-b). Caterpillars in the West are present on tomato crop every year since the beginning of the crop (3 growers out of 5) (questions nos. 14-b and 14-c).

This situation, with a predominant importance of aerial diseases, was already expected from the information collected during the informal survey done during the first part of the research project and from the literature review. As a consequence question no. 14-j was included in the survey questionnaire and the analysis of the results clearly shows that at the moment caterpillars are the only arthropod pest problem feared by the growers in the West, while in the Algarve they pointed out both caterpillars and spider mites (Table 5.17).

For **melon** all the growers in the Algarve answered question no. 10 but in the West only 5 of the surveyed growers answered this question, suggesting that in spite of the fact that 10 of the surveyed growers were growing or planning to grow this crop (Table 5.7) the experience and accumulated knowledge on this crop is still poor on a regional basis (new crop in the area).

In the Algarve the predominant pest problems are *Fusarium* wilt (24 growers), powdery mildew (21), spider mites (20), aphids (16), whiteflies (13) and nematodes (10) (Fig. 5.18). Spider mites seem to be mainly active in the spring. In the West, powdery mildew (4 growers) and *Fusarium* wilt (3) seem to be the prevailing pest problems on this crop (Fig. 5.18 and Table 5.18).

The most important pest problems on melon (question no. 14--a) were indicated by 20 growers in the Algarve who considered melon the second most important crop. In the West no grower considered melon the second most important crop and as a consequence no further information on pest problems other than that already reported in Fig. 5.18 was collected for the melon crop in the West. However, the data suggests that in the West the growers are facing exactly the same problems reported from the Algarve.

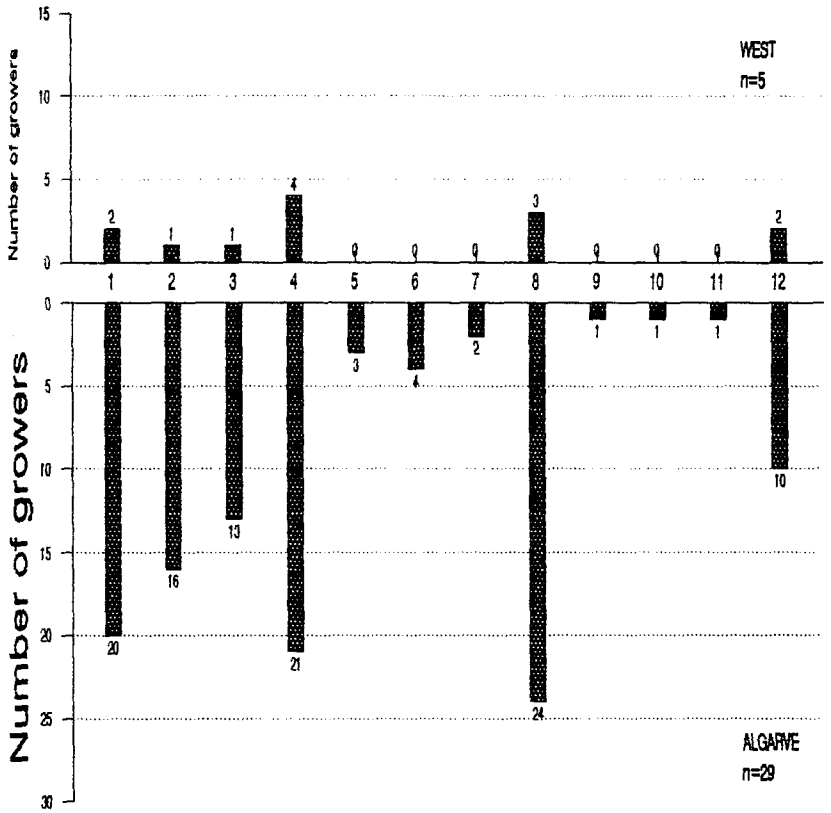


Fig. 5.18 - Pest(*) problems indicated by the surveyed growers for the melon crop.

1 - Spider mites
2 - Aphids
3 - Whiteflies
4 - Powdery mildew
5 - Root rot
6 - Grey mould
7 - Downy mildew
8 - *Fusarium* wilt
9 - *Sclerotinia* white rot
10 - Wilting
11 - Anthracnose
12 - Nematodes

(*) - According to the legend of Fig. 5.17.

Fusarium wilt, powdery mildew and nematodes are the most important pest problems on this crop (Table 5.19) and all of them were among the most predominant problems too, suggesting that technical solutions are lacking or are not readily available to the growers. The cultivar Harvest King is considered particularly prone to attack by powdery mildew by some growers (5 growers stated that in the Algarve).

Table 5.18 - Periods of occurrence for the major pest problems, on melon in the Algarve, according to the growers' perceptions.

time	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Fev	Mar	Apr	Mai	Jun	Jul	GROWERS' REMARKS
Cropping-cycle of the melon crop in the Algarve (*).							ǂ....N.....								
								\ǂ.....G.....							
											\ǂ.....H.....				
Fusarium WILT									...XXXXXXXXXX...						
POWDERY MILDEW										...XXXXXXXXXXXXXXXXXXX...					During the second half of the crop; a permanent threat to the crop
WHITEFLIES									...XXXXXXXXXX...						Attacks when the plants are small
APHIDS										...XXXXXXX...					Attacks when the plants are small
SPIDER MITES								...XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX...							During hot weather; they can attack during all the crop season; attacks begin in the central area of greenhouse

(*) : N - nursery period; G - vegetative growing period; H - harvest period

Table 5.19 - Most important pest problems on melon according to the growers' perceptions

REGION	WEST	ALGARVE
WORST PEST PROBLEM		*Fusarium* (10)‡ Powdery mildew (5) Nematodes (3) Spider mites (1) Soil fungi (1)
--	--	--
‡‡		20
SECOND WORST PEST PROBLEM		Powdery mildew (5) *Fusarium* (4) Nematodes (3) Spider mites (2) Soil fungi (1) Whiteflies (1) Aphids (1)
--	--	--
‡‡		17
MAJOR ARTHROPOD PEST PROBLEM		Spider mites (6) Whiteflies (2) Aphids (1)
--	--	--
‡‡		9

‡ - Number of growers indicating this pest
‡‡ - Number of growers answering this question

Fusarium wilt begins causing problems on melon on average after the third year of the crop (9 growers out of 14), but in two cases the disease was noticed after the first year of the crop (question no. 14-b). Nematodes were noticed on average after 4 years with the crop (4 growers out of 6) (question no. 14-b). By contrast, powdery mildew is regarded as a pathogen causing problems every year, from the first year of the crop by the majority of the growers who mentioned this pest problem (7 growers out of 10) (questions nos. 14-b and 14-c) and according to one grower

in the Algarve "*...the attacks of this pathogen begin in the central area of the greenhouse, on the spots with higher temperature...*".

Since no arthropod pest was considered a major pest, question no. 14-j was again very helpful to clarify which arthropod pests were perceived as "at least secondary" ones by the growers. Spider mites were reported as the most injurious arthropods on this crop (Table 5.19) and, as in the powdery mildew situation, the attacks of spider mites are noticed first "*...in the central areas of the greenhouse, on the spots with higher temperature...*" (Table 5.18).

On **green beans** 27 growers in the West and 25 growers in the Algarve gave information about the pest problems of the crop (question no. 10). The most frequent problems pointed out in the West were *Fusarium* (15 growers), spider mites (14), grey mould (13), aphids (10) and nematodes (9) (Fig. 5.19). In the Algarve the predominant pest problems were spider mites (20 growers), grey mould (19), aphids (15), rust (9) and powdery mildew (7) (Fig. 5.19).

Aphids seem to be present on this crop essentially in the spring in the West, the period of attack ranging from mid March to May according to the growers' opinion. In the Algarve aphids are perceived on the crops either during the winter season, from the beginning of the crop, or later in the season during hot weather periods (Tables 5.20 and 5.21).

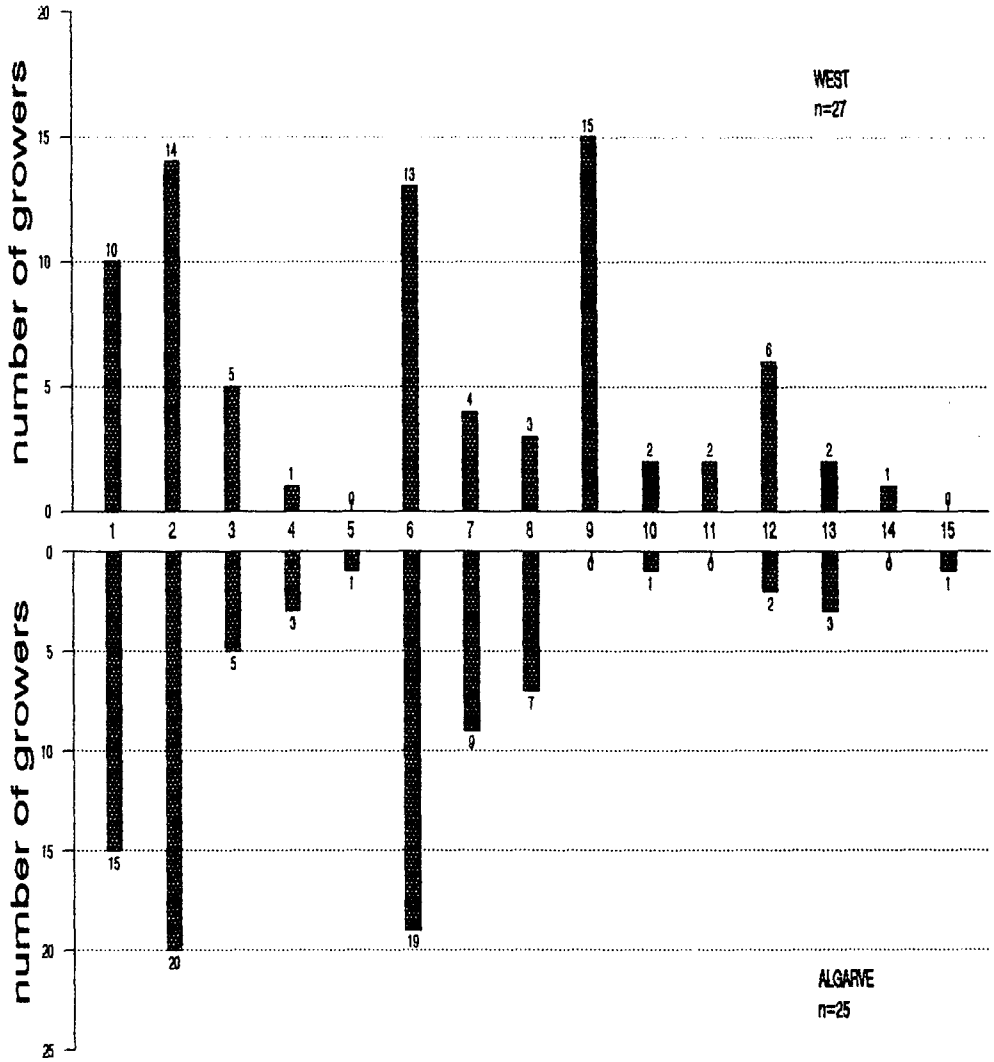


Fig. 5.19 - Pest(*) problems indicated by the surveyed growers for the green bean crop.

1 - Aphids
2 - Spider mites
3 - Whiteflies
4 - Caterpillars
5 - Soil pests
6 - Grey mould
7 - Rust
8 - Powdery mildew
9 - *Fusarium*
10 - *Pythium*
11 - Blight
12 - Nematodes
13 - Bacteria
14 - Viruses
15 - Birds

(*) - According to the legend of Fig. 5.17.

In the Algarve spider mites can occur either during the autumn crop (October-November) or later during the spring crop, as early as February-March until the end of the crop, in hot weather conditions. Their attacks are noticed in patches. In the West spider mites are perceived late in the

spring, from April-May to the end of the crop season, during hot and dry weather (Tables 5.20 and 5.21).

Table 5.20 - Periods of occurrence for the major pest problems, on green beans in the West, according to the growers' perceptions.

time	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Fev	Mar	Apr	Mai	Jun	Jul	GROWERS' REMARKS
Cropping-cycle of the green beans in the West (*).							ǂ.....G.....			\ǂ.....H.....					
Fusarium WILT								...XXXXXXX...							Symptoms are visible when the plants reach two true leaves stage; hypocothyl and roots reddish; worst in wet soil areas
GREY MOULD								...XXXXXXXXXXXXXXXXXXXXXXXXXX...							can cause troubles during all the crop season; worst on the pods, during humid weather
RUST								...XXXXXXXXXXX...							Linked with: humid, foggy weather
BACTERIA										...XXXXXXXXXX...					
WHITEFLIES										...XXXXXXXXXXXXXXX...					Linked with: hot weather
APHIDS									...XXXXXXXXXXXXXX...						One month after the beginning of the crop
SPIDER MITES											...XXXXXXXXXXXXXXXXX...				During hot and dry weather; after crop flowering

(*) : G - vegetative growing period; H - harvest period

The occurrence of rust on green beans in the West was linked to foggy weather and periods with high moisture by

several growers, which agrees with the environmental requirements of the fungi (Table 5.20).

Two growers in the West indicated the occurrence of a blight disease affecting green beans. Unfortunately it was impossible to identify which disease the growers were reporting. Since neither the growers' ability to recognise or identify pests and disease symptoms was assessed nor the accuracy of their perceptions in terms of pest problems present "*de facto*" on their crops, it is possible to argue that the pest problems pointed out by the growers could in some cases be missidentified. That could happen, especially with pest problems new in the area or with diseases showing symptoms which are not very specific or that could be easily mistaken. However, most of the time growers pointed out groups of widely known harmful organisms (like aphids, caterpillars, root-knot nematodes) which reduces this risk. Even when they indicated specific problems (like *Fusarium* wilt), that shows how the growers perceive the problem according to the information they have. The pest problems they try to solve are those which they perceive as actual or potential problems, irrespective of the accuracy of the identification.

Only 6 growers indicated green beans as the second most important crop in the Algarve, while in the West 23 growers indicated this crop (question 14). From the latter group, 3 of them did not indicate any pest problem considered important in the crop and the remaining 20 pointed out grey mould (9 growers) and *Fusarium* (6 growers) as worst pest

problems (Table 5.22).

Table 5.21 - Periods of occurrence for the major pest problems, on green beans in the Algarve, according to the growers' perceptions.

time	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Fev	Mar	Apr	Mai	Jun	Jul	GROWERS' REMARKS
Cropping-cycle of the green beans in the Algarve (*).			‡.....G.....			\‡.....H.....			‡.....G.....		\‡.....H.....				
GREY MOULD					...XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX...										In humid weather, during all the winter, till April
RUST						...XXXXXXXXXXXXXXXXXXXXXX...									During the winter
POWDERY MILDEW											...XXXXXXXXXXXX...				During spring-summer
WHITEFLIES											...XXXXXXXXXXXXXXXX...				During spring-summer
APHIDS					...XXXXXXXXXXXXXXX...					...XXXXXXXXXXXXXXXX...					Since the beginning of the crop; during winter as well as spring-summer
SPIDER MITES				...XXXXXXXXXX...				...XXXXXXXXXXXXXXXXXXXXXXXXX...							During hot weather; at the final phase of the crop; in summer time

(*) : G - vegetative growing period; H - harvest period

In the West grey mould is regarded as causing problems every year (12 growers out of 13) (question no. 14-c), from the beginning of the crop; *Fusarium* wilt begins after the second year with the crop on average (6 growers out of 8) (question no. 14-c). In the Algarve all 6 growers indicated grey mould and 2 growers considered powdery mildew the second worst pest problem (Table 5.22). Half of

the growers (3 out of 6) consider that grey mould causes problems every year from the beginning of the crop (questions nos. 14-b and 14-c). One grower indicated that powdery mildew appears every year from the beginning of the crop.

Table 5.22 - Most important pest problems on green beans according to the growers' perceptions

REGION	WEST	ALGARVE
WORST PEST PROBLEM	Grey mould (9)*	Grey mould (6)
	Fusarium (6)	
	Spider mites (2)	
	Soil fungi (1)	
	Whiteflies (1)	
	Aphids (1)	
--	--	--
**	20	6
SECOND WORST PEST PROBLEM	Grey mould (4)	Powdery mildew (2)
	Fusarium (2)	Spider mites (1)
	Blight (2)	
	Spider mites (1)	
	Soil fungi (1)	
	Nematodes (1)	
	Rust (1)	
--	--	--
**	12	3
MAJOR ARTHROPOD PEST PROBLEM	Spider mites (9)	Spider mites (5)
	Aphids (2)	Aphids (1)
--	--	--
**	11	6

* - Number of growers indicating this pest
** - Number of growers answering this question

In both regions spider mites are regarded as the major arthropod pest problem by the growers (Table 5.22).

Concerning pest problems on Sweet pepper, 22 growers in the Algarve and 5 growers in the West answered question no. 10 and the predominant pest problems indicated in the Algarve were aphids (18 growers), viruses (12), powdery mildew (9) and spider mites (8) (Fig. 5.20). Aphids, as well as viruses, are perceived mainly during winter time. Spider mites are noticed on the crop during the autumn (October--November) and in the spring, after March, with their attacks being associated with hot and dry weather (Table 5.23). In the West powdery mildew (2 growers) and caterpillars (2 growers) seem to be the most prevalent pest problems (Fig. 5.20).

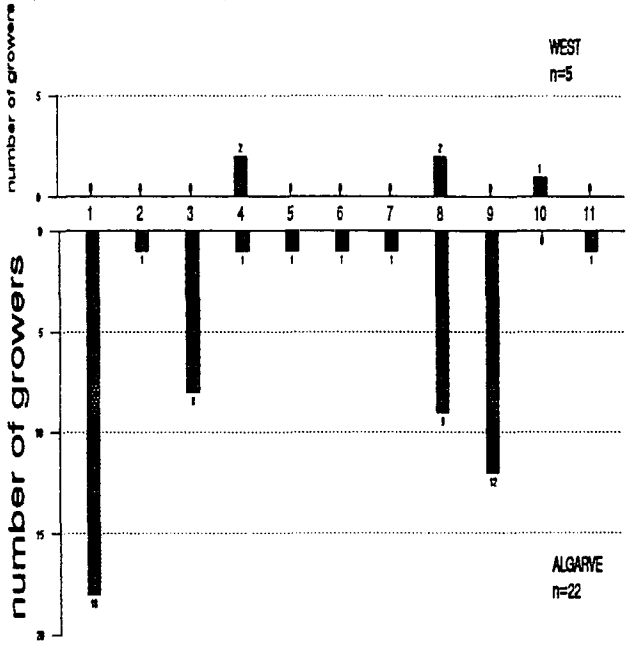


Fig. 5.20 - Pest(*) problems and physiological disorders indicated by the surveyed growers for the sweet pepper crop.

1 - Aphids
2 - Whiteflies
3 - Spider mites
4 - Caterpillars
5 - Russet mites
6 - Blight
7 - Grey mould
8 - Powdery mildew
9 - Viruses
10 - Nematodes
11 - Blossom end rot (physiological disorder)

(*) - According to the legend of Fig. 5.17.

Only 3 growers in the Algarve considered sweet pepper the second most important crop (question 14) and for that reason the information obtained in the survey concerning the worst pest problems in this crop was consequently reduced. The worst pest problems pointed out by the growers (questions nos. 14-a and 14-j) were powdery mildew, viruses and blight and these pathogens seem to be present every year from the beginning of the crop; aphids and spider mites were the worst arthropod pests (Table 5.24). Like in the green bean situation, it was impossible to identify which disease the grower was reporting when he mentioned sweet pepper blight.

Table 5.23 - Periods of occurrence for the major pest problems, on sweet pepper in the Algarve, according to the growers' perceptions.

time	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Fev	Mar	Apr	Mai	Jun	Jul	GROWERS' REMARKS
Cropping-cycle of the sweet pepper crop in the Algarve(*)			‡....N.....				‡.....N.....								
				\‡.....G.....					\‡.....G.....						
												\‡.....H.....			
							\‡.....H.....								
VIRUSES					...XXXXXXXXXXXXXXXXX...										During winter time
WHITEFLIES				...XXXXXX...								...XXXXXXXXXX...			During summer time
APHIDS					...XXXXXXXXXXXXXXXXX...										Mainly during winter time
SPIDER MITES					...XXXXXXXXXX...				...XXXXXXXXXX...						During hot and dry weather; earlier in the crop season

(*) : N - nursery period; G - vegetative growing period; H - harvest period

Table 5.24 - Most important pest problems on sweet pepper according to the growers' perceptions

REGION	WEST	ALGARVE
WORST PEST PROBLEM		Powdery mildew (1)* Viruses (1) Blight (1)
--	--	--
**		3
SECOND WORST PEST PROBLEM		Grey mould (1) Aphids (1)
--	--	--
**		2
MAJOR ARTHROPOD PEST PROBLEM		Aphids (1) Spider mites (1)
--	--	--
**		2

* - Number of growers indicating this pest
** - Number of growers answering this question

The predominant pest problems on <u>cucumber</u> were indicated by 15 growers in the Algarve and 7 growers in the West. Powdery mildew (11 growers), spider mites (7) and aphids (6) were the prevalent pest problems in the Algarve (Fig. 5.21) and powdery mildew (2 growers) and aphids (2) were the prevailing pest problems on cucumber in the West (Fig. 5.21).

Only 1 grower in the west indicated cucumber as the second most important crop (question no. 14) and he perceived powdery mildew as the worst pest problem on this crop (question no. 14-a). This pathogen causes troubles from the beginning of the crop (question no. 14-b).

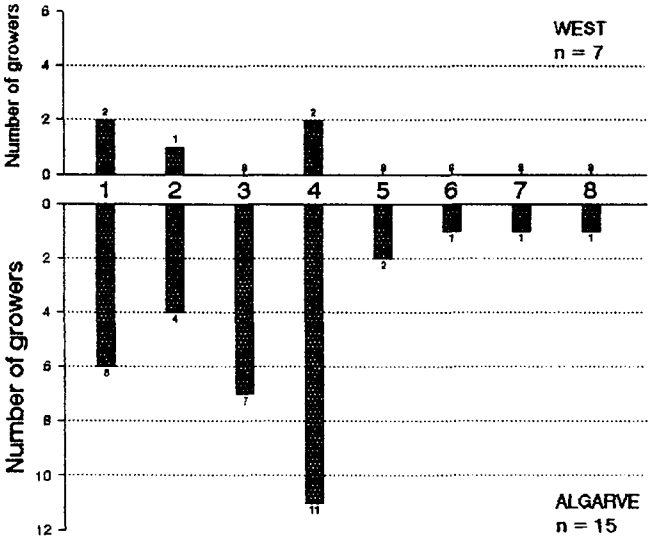


Fig. 5.21 - Pest(*) problems indicated by the surveyed growers for the cucumber crop.

1 - Aphids
2 - Whiteflies
3 - Spider mites
4 - Powdery mildew
5 - Grey mould
6 - Downy mildew
7 - *Fusarium*
8 - Nematodes

(*) - According to the legend of Fig. 5.17.

The predominant pest problems on <u>lettuce</u> (question no. 10) were only indicated by 7 growers in the West and *Sclerotinia* disease/grey mould complex (5 growers) and nematodes (2) were the prevailing pest problems on this crop (Fig. 5.22).

In the West 3 growers indicated lettuce as the most important crop and two of them considered *Sclerotinia* disease/grey mould complex the worst pest problem on the crop, appearing every year, while the other grower perceived cutworms as the worst pest problem on this crop, specially during the first year of the crop.

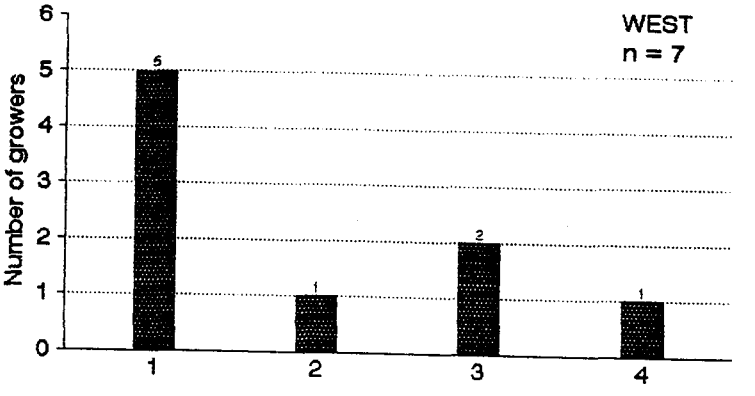


Fig. 5.22 - Pest(*) problems indicated by the surveyed growers for the lettuce crop.

1 - *Sclerotinia* disease / Grey mould
2 - Downy mildew
3 - Nematodes
4 - Caterpillars

(*) - According to the legend of Fig. 5.17.

Apart from the pest problems mentioned above, occurring on the actual crops, growers also face **pest problems attacking the seedlings during the nursery period**. In both regions many of the growers producing their own seedlings reported this fact (52% (12/23) in the Algarve and 33% (10/30) in the West) (question no. 18), but there are no significant differences between the regions concerning the distribution of the number of growers with and without pest attacks during the nursery period ($X^2_{[1]}$ = 1.90 (n.s.)).

Tomato was reported as the most affected plant during the nursery period (9 growers in each of the regions reported that) while melon was indicated by 4 growers in the Algarve; in the West melon and sweet pepper were indicated by one grower only.

The pest problems pointed out (question no. 18) are shown in Fig. 5.23. In the Algarve the most frequent problems in nurseries seem to be soil-borne fungi (like *Phytophthora, Pythium, Verticillium* and *Fusarium* species), late blight and slugs/snails. In the West late blight seems to be the most common pathogen affecting plants in nurseries, but soil-borne fungi and some insects (leafminers, whiteflies) were also reported.

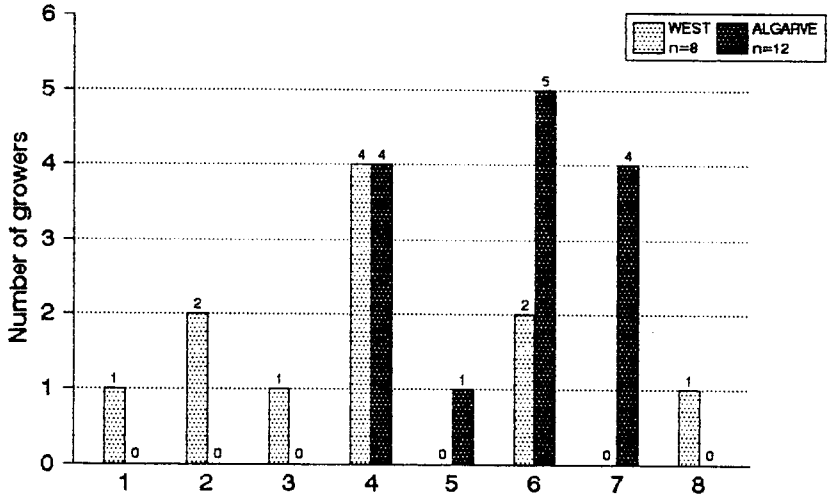


Fig. 5.23 - Pest problems indicated by the surveyed growers occurring during the nursery period

1 - Whiteflies
2 - Leafminers
3 - Soil Pests
4 - Late blight
5 - Grey mould
6 - Soil fungi
7 - Slugs / Snails
8 - Birds

For the growers who bought transplants (2 growers in the West and 6 growers in the Algarve), only in the West the growers claimed that tomato transplants were infected, one by viruses and the other by *Fusarium* wilt (question no. 18). Apparently in the Algarve the commercial nurseries are providing transplants to the growers with good quality standards.

5.3.6.3 - Weed control methods

Inside greenhouses, growers mainly solve the weed problems using two different strategies (question no. 11-c): hand weeding/hoeing and plastic mulching of the soil along the line of the plants.

In the West two or three hand weeding/hoeing operations through the season on tomato and green bean crops are the prevailing strategies adopted by the growers while in the Algarve the majority of the surveyed growers used plastic mulching to prevent weed infestations on tomato and melon crops (Table 5.25). The plastic used on tomato to mulch the soil is black in almost all cases (15 growers are using or have already used black plastic and only 2 growers indicated white plastic) while on melon both plastic colours are equally used, sometimes by the same grower, according to his judgement of the crop conditions (transplanted crops or crops in greenhouses with high weed densities are linked with black plastic; sown crops or crops in greenhouses with low weed densities or, alternatively, if the grower wants to advance the earliness of the crop, are conditions linked with white plastic).

Only two growers in the Algarve apply herbicides (question no. 11-e) to control weeds in tomato and both of them apply metribuzin after seedlings transplant (Table 5.25).

In the West three of the surveyed growers used to earth-up around the stems of green bean plants and they claimed

that they destroy the young weeds through this operation regularly repeated during the first phase of the crop season.

Table 5.25 - Weed control methods adopted by the surveyed growers inside greenhouses

CROPS \ STRATEGIES / Region	A	B	C	D	E	F	G	H	No. of growers answering this question
TOMATO West	5*	9	9	3	5	1			32
TOMATO Algarve	1	2	4	2	3		2	14	28
GREEN BEANS West	4	5	5	1	2	3			20
GREEN BEANS Algarve		1	1						2
MELON Algarve		1	3	1				12	17
SWEET PEPPER Algarve		1							1
LETTUCE West	1	1	1	1					4

* - Number of growers indicating this strategy

STRATEGIES : A - Hand weeding/hoeing once a season
B - Hand weeding/hoeing twice a season
C - Hand weeding/hoeing three times per season
D - Hand weeding/hoeing four times per season
E - Hand weeding/hoeing more than four times per season
F - Earthing-up along the line of the plants
G - Herbicides
H - Plastic mulching along the line of the plants

The majority of the growers maintain the same weed control method adopted when they began producing the crop inside greenhouses (question no. 11-d). However, some growers have already tried other strategies to control weeds different from the control method actually employed (Table 5.26).

This is particularly evident in the Algarve for tomato and melon crops where some growers were not satisfied with plastic mulching (6 growers) and adopted hand weeding/hoeing techniques while the growers that previously used herbicides adopted either plastic mulching (3 growers) or hand weeding/hoeing (3 growers). By contrast the growers not happy with hand weeding/hoeing techniques adopted herbicides (1 grower) and plastic mulching (1 grower).

The three growers who changed weed control method from herbicides to plastic mulching on tomato in the Algarve claimed that they were satisfied with the results obtained with metribuzin when they used furrow irrigation. However, since they changed the irrigation system to drip irrigation the amount of water available through the irrigation was not enough to incorporate herbicides into the soil and as a consequence they got very poor weed control. Therefore, three of them changed to plastic mulching.

In fact the irrigation system employed inside greenhouses is perceived by some growers as a determinant factor affecting weed density, which was clearly put by one grower's statement in the West: "...*before (the use of) drip irrigation, furrow irrigation allowed a very important development of weeds...*".

The other three growers who changed weed control on tomato in the Algarve from herbicides to hand weeding/hoeing applied dinitramine (2 growers) and paraquat (1 grower) while in the West glyphosate (2 growers) and paraquat (1

grower) were the herbicides used in the past by the growers who changed weed control strategy. On melon, 1 grower applied dinitramine and trifluralin was used on sweet pepper by 1 grower, both in the Algarve (Table 5.26).

Table 5.26 - Growers who changed weed control strategies in the past and control methods employed

CROPS \ STRATEGIES	Region	A	B	C	D	No. of growers answering this question
TOMATO	West	28*	3	1		32
	Algarve	15	6	6	2	29
GREEN BEANS	West	20				20
	Algarve	2				2
MELON	Algarve	13	1	3	1	18
SWEET PEPPER	Algarve		1			1
LETTUCE	West	4				4

* - Number of growers indicating this strategy

STRATEGIES : A - Growers who didn't change weed control methods
B - Growers who used herbicides
C - Growers who used plastic mulching
D - Growers who used hand weeding/hoeing

Outside, around greenhouses (question no. 13), the majority of the growers destroy the natural vegetation growing in the vicinity of the greenhouses (30 growers in the West and 23 in the Algarve perform this operation, while 2 growers in the West and 6 in the Algarve do not). The reasons they gave for such an operation are mainly: a) they like to keep the area around the greenhouse clean (7 growers in the West

and 3 growers in the Algarve gave this reason); b) because natural vegetation around greenhouses can act as a reservoir for pests (8 growers in the West and 2 growers in the Algarve) and c) to allow an easy drainage of surface waters around greenhouses (4 growers in the West and 3 growers in the Algarve). It seems, however, that the growers regard this task as a second priority operation since some of them clearly state that they only perform this activity if and when they have available time, in spite of the fact of being aware of the undesirable effects caused by its delay (3 growers in the Algarve and 1 grower in the West). The application of paraquat and hand weeding/hoeing are the major techniques employed by the growers to destroy plants around greenhouses (Table 5.27), and some of them use two different methods at different times of the year.

Table 5.27 - How growers destroy natural vegetation around greenhouses

CONTROL \ REGION / METHOD \	ALGARVE	WEST
HERBICIDES: paraquat	13*	23
HERBICIDES: glyphosate	1	5
HERBICIDES: simazine + aminotriazole	2	4
HERBICIDES: metribuzin	1	
Hand weeding/hoeing	13	8

* - No. of growers who use this method

5.3.6.4 - Control of arthropods and diseases

Growers rely almost exclusively on chemical control to solve the pest problems they are confronted with on every crop they grow inside greenhouses (questions nos. 14-d and 17). The active ingredients (a.i.) used by the growers to control the pest problems perceived as the two worst ones on the major crops (question no. 14-d1) are represented in Figs. 5.24, 5.25, 5.26 and 5.27.

For the two major problems in tomato crop (grey mould and late blight (Table 5.17)), grey mould is mainly controlled with dicarboximides (vinclozolin, procymidone, iprodione) and the benzimidazole benomyl, in both geographical regions (Fig. 5.24). In the West the phthalimide dichlofluanid is also popular amongst growers while a few growers in the Algarve also applied the benzimidazole thiophanate-methyl (Fig. 5.24), which is not cleared for use in the tomato crop.

In the West growers employ, on average, 3 different pesticides through the season to control grey mould (procymidone, iprodione, vinclozolin and dichlofluanid, procymidone, vinclozolin are the most frequent combinations) while in the Algarve only two pesticides are employed, on average (with no particular pesticide combination more frequent than others) (question no. 14--d1). In the West the spraying interval is 7 days on average, when this pest problem is considered the worst

one, and 9 days when grey mould is considered the second worst pest problem, while in the Algarve these values are respectively 8 and 9 days (question no. 14-d3). The spraying interval is generally weather dependent and the values indicated by growers vary from 3 days to 20 days.

The use of dichlofluanid in the West involves two different strategies: some growers apply this a.i. during the first phase of the crop as a preventive fungicide before important attacks of the pathogen and later change to dicarboximides (6 growers considering grey mould the worst pest problem and 1 considering this pathogen the second one employ this strategy); other growers alternate this a.i. with the other pesticides they apply for grey mould control (6 growers considering this pathogen the worst pest problem and 1 considering the second one have this behaviour).

Vinclozolin is mainly applied during the last phase of the crop, particularly in the West, and growers avoid spraying this pesticide when the number of flowers is high, since they perceive this a.i. as phytotoxic to flowers, causing high abortion levels.

The decision factor employed by the growers in both regions to begin this scheduled spraying depends either on environmental factors or on a time scale which can be judged by calendar time or by the phenological development of the crop. The environmental factors pointed out include ..."*when the weather becomes damp*"; "*when the rainy season begins*"; "*during periods with very intense raining*"; "*when*

the weather becomes wet and rainy"...; the calendar decision factors include ..."*5 weeks after transplanting of the seedlings*"; "*one and a half months after transplanting*"; "*two months after transplanting*"...; the phenological stages used as decision factors vary from ..."*when the cut of the axillary shoots begins*"; "*when the first flowers appear*"; "*when the first fruits become visible*"... to ..."*when the fourth tomato cluster appears*"; "*when the tomatoes are already well developed*"...

The number of growers exceeding the recommended concentration of pesticides in the West (12 growers out of 19 indicating grey mould as the worst pest problem and 3 out of 7 indicating this pest problem as the second worst one increased the pesticides' concentration applied on the crop) do not differ significantly from the number of growers having the same behaviour in the Algarve (9 growers out of 20 indicating this pathogen as the worst pest problem and 2 out of 5 indicating this pest problem as the second worst one) ($X^2_{[1]} = 0.96$ (n.s.)).

Among those growers who exceed the recommended concentration, in the West 26% (5/19) of the growers from the group considering grey mould the worst pest problem in the tomato crop increase 100% while all the others increase 50% or less; by contrast in the Algarve only 1 grower belonging to the group of the worst pest problem increases the concentration more than 50%, but surprisingly he exceeds the recommended concentration by 200% (question no. 14-d4).

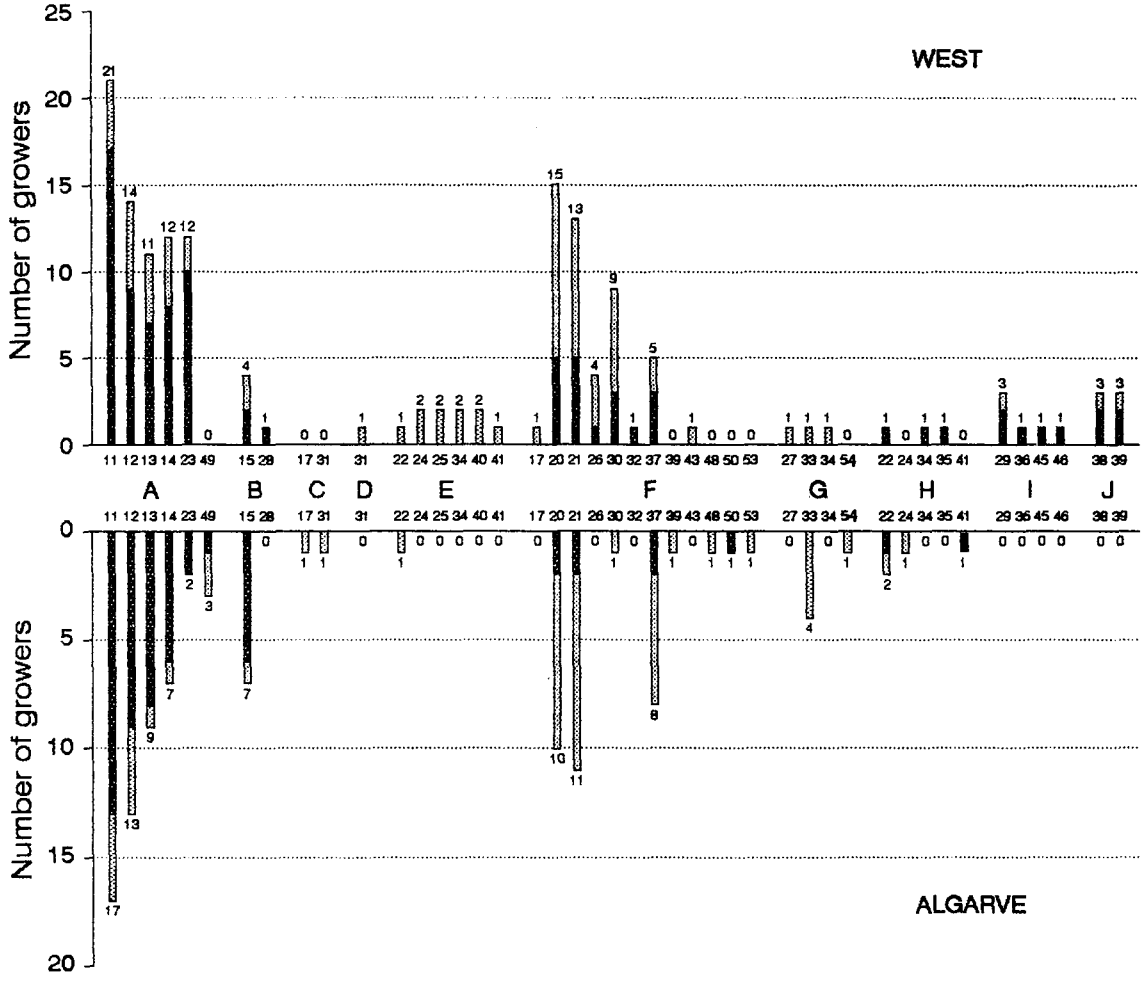


Fig. 5.24 - Pesticides applied by the growers against the worst pest problems in the tomato crop

(the pesticide legend of this figure is in next page)

PEST PROBLEMS - considered the worst pest problem - considered the second worst pest problem

A - Grey mould

B - Nematodes

C - Soil fungi

D - *Fusarium* wilt

E - Caterpillars

F - Late blight

G - Spider mites

H - Whiteflies

I - Powdery mildew

J - Bacteria

11 - vinclozolin
12 - procymidone
13 - iprodione
14 - benomyl
15 - fenamiphos
16 - thiabendazole
17 - thiram
18 - carbendazim
19 - carbofuran
20 - mancozeb
21 - cymoxanil
22 - deltamethrin
23 - dichlofluanid
24 - methamidophos
25 - trichlorfon
26 - folpet
27 - cyhexatin
28 - oxamyl
29 - triadimefon
30 - metalaxyl
31 - propamocarb hydrochloride
32 - copper oxychloride + Zineb
33 - dicofol + tetradifon
34 - cypermethrin
35 - alphamethrin
36 - penconazole
37 - propineb
38 - kasugamycin
39 - copper sulphate
40 - methomyl
41 - endosulfan
42 - parathion
43 - ziram
44 - pirimicarb
45 - dinocap
46 - pyrazophos
47 - quinomethionate
48 - zineb
49 - thiophanate-methyl
50 - metiram
51 - fenarimol
52 - nuarimol
53 - captafol + folpet + ofurace
54 - phosalone
55 - dazomet
56 - methyl bromide
57 - lindane
58 - azinphos-ethyl
59 - polyoxin B
60 - quintozene
61 - diazinon
62 - chlordane + lindane
63 - fonofos
64 - chlorpyrifos
65 - aldrin
66 - sulphur
67 - mercaptodimethur
68 - aluminium phosethyl

About one third of the growers considering grey mould the worst pest problem changed pesticides against this pathogen in the last 3-4 years (6 growers in the West and 7 growers in the Algarve) (question no. 14-d5) and more than half of these growers are planning to apply the same a.i. next season (13 growers in the West and 11 growers in the Algarve) (question no. 14-e). From the group considering this pest the second worst problem no grower changed pesticides in the last 3-4 years and again more than half of these growers are planning to apply the same pesticides next season.

Late blight is mainly controlled in both regions with dithiocarbamate fungicides (mancozeb, propineb) or with the new systemic fungicides cymoxanil (cianoacetamide--oxime) and metalaxyl (acylalanine), both of them formulated in mixtures: the former a.i. mainly with propineb and the latter with mancozeb, folpet or copper oxychloride (Fig. 5.24). On average, every grower in both regions applies three different pesticides through the season to control late blight in tomato (question no. 14--d1). One grower in the West sprayed ziram and thiram against late blight but neither a.i. is cleared to be used on tomato against this disease.

As reported in Chapter 3.4, in 1984-85 systemic fungicides were not yet very popular among growers in the Algarve, but according to the present survey the situation changed completely in the last three years, with growers nowadays using systemic fungicides against late blight profusely in both regions. Growers usually employ dithiocarbamates in the beginning of the crop and later in the season, or if they spot any symptoms of the disease, they change to mixtures with systemic fungicides.

The spraying interval is, on average, 7 days in both regions when late blight is considered the worst pest problem in tomato (2 growers in the Algarve and six growers in the West) but it changes to 6 days in the West (11 growers) and 9 days in the Algarve (11 growers) when late blight is regarded as the second worst pest problem (question no. 14-d3). However, the growers adjust this

scheduled interval according to weather conditions: in the West 6 growers spray regularly twice a week during rainy or very wet periods; during summer time 8 growers in the West and 12 in the Algarve spray only every 12-15 days.

Almost all growers begin the spraying against late blight two weeks after transplanting or, alternatively, one week after it.

The number of growers exceeding the recommended concentration in the West (10 growers out of 11 from the group who consider late blight the second worst pest problem and 2 growers out of 6 who consider this pest problem the worst one) is greater than the number in the Algarve (5 growers out of 11 from the group indicating late blight the second worst pest problem and no grower out of the 2 who consider late blight the worst pest problem) (question no. 14-d4). However, there are no significant differences between the regions concerning the distribution of the growers who exceed the recommended concentration ($X^2_{[1]} = 3.1$ ($p<0.1$)).

The majority of the growers are planning to apply the same control method next season (9 growers out of 13 in the Algarve and 11 growers out of 17 in the West) (question no. 14-e).

To control root-knot nematodes, fenamiphos is the most applied a.i. in both regions but oxamyl is beginning to be used at least in the West (Fig. 5.24).

In the Algarve growers apply fenamiphos two (4 growers) or three times (2 growers) if nematodes are considered the worst pest problem, but they apply only once if this problem is the second worst one (1 grower). The timing for application has two distinct patterns: some growers do the first treatment before transplanting of the crop (when they perform the pre-planting fertilisation) and the second one 15 days after the transplanting; other growers do the first treatment immediately after transplanting, the second one 15 days or one month after the first treatment and, eventually, a third treatment 15 days after the second. In the West growers always seem to apply two treatments (question no. 14-d3), the first treatment immediately after transplanting and the second one 15 days or one month after the first application.

The majority of growers in both regions apply the recommended concentration but one grower in each region belonging to the group indicating nematodes as the worst pest problem exceeded the recommended concentration (question no. 14-d4).

Caterpillars are controlled with a wide group of pesticides, ranging from the pyrethroids (deltamethrin, cypermethrin), OP's (methamidophos, trichlorfon), carbamates (methomyl) to the old organochloride compounds (endosulfan) (Fig. 5.24).

The growers employ two different strategies to fight caterpillars: one group applies insecticides preventively,

in mixtures with other pesticides applied for late blight and/or grey mould control (9 growers in the West and 11 in the Algarve have this behaviour) and in this case the spraying interval is the same previously indicated for late blight; another group applies insecticides only when they see the pest (7 growers in the West and 5 in the Algarve indicated this strategy) and in this case the number of sprays varies between 2 and 4 per season.

There are no significant difference between the regions concerning the utilisation by the growers of these two strategies ($X^2_{[1]} = 0.53$ (n.s.)). Only one grower in the West (out of 5) exceeded the recommended concentration (a 50% increase).

Specifically to fight cutworms, two growers in the Algarve mixed trichlorfon with ground carob pods which they spread over the soil as a bait while in the West one grower applied parathion through the irrigation system.

Bacteria were regarded as a major pathogen by some growers in the West (Table 5.17). All of them tried to solve this problem applying kasugamycin and copper sulphate. Kasugamycin, an antibiotic produced by *Streptomyces kasugaensis*, was first developed in Japan as a fungicide against *Pyricularia oryzae*, but it also inhibits the growth of several bacteria, notably some *Pseudomonas* species (Misato *et al.*, 1977; Misato, 1984), like *P. glumae* on rice, *P. syringae* pv. *lachrymans* on cucumber and *P. syringae* pv. *phaseolicola* on kidney beans (Worthing, 1987).

However, there is no evidence that this product will be effective against gram-positive bacteria (which is the case with tomato canker caused by *Clavibacter michiganense* subsp. *michiganense*), since with the exception of *Pseudomonas* species, the antibacterial properties of kasugamycin are weak (Davidse & Waard, 1984). This reason could explain why one grower in the West claimed that this chemical had no effect on tomato bacteria and this brings back again the problem of correct identification of the pest problems by the growers.

As stated in Chapter 3.4, antibiotics have not been approved for agricultural purposes by the Portuguese pesticides approval scheme (a legal requirement under the control of the Ministry of Agriculture and the Ministry of Trade), so the selling and application of this pesticide is not allowed in Portugal. However, the growers are getting it illegally.

On melon *Fusarium* wilt and powdery mildew were considered the two worst pest problems in the Algarve (Table 5.19).

Half of the growers who indicated *Fusarium* wilt are trying to control the disease with fungicides (7 growers) and they are mainly applying benomyl drenches (Fig. 5.25). Nevertheless, some growers are trying other fungicides recommended for different soil fungi, particularly propamocarb hydrochloride (carbamate) (specific recommended against soil-borne oomycetous fungi, which of course is not the present case) and thiram (dithiocarbamate) (generally

recommended against "damping-off" causal agents in several crops), which suggests that growers are trying pesticides by trial and error and they have lack of reliable technical information.

The application of chemical control seems to be greater amongst the growers who indicated *Fusarium* wilt as the worst pest problem (6 growers out of 10) than amongst those who indicated *Fusarium* wilt as the second worst pest problem (1 grower out of 4).

The number of pesticide applications ranges from 1 to 3 (on average two applications), performed either in the nursery and immediately after transplanting or, alternatively, when the plants reach 20-30 cm of height. Usually, the growers apply the recommended concentration with the exception of one grower who exceeded the recommended concentration by 50% (questions nos. 14- d3 and 14-d4).

Powdery mildew in melon is mainly controlled with triadimefon (triazole), quinomethionate (quinolaxine) and fenarimol (pyrimidine) (Fig. 5.25), which agrees with the information presented in Chapter 3.4 and shows that in the recent past growers maintained the control method against this pest problem, in spite of the fact that 40% of the growers (4 out of 10) changed the pesticides employed in the last 3-4 years (question no. 14-d5) and only half of the growers (5 out of 10) are planning to use the same pesticides in the next season (question no. 14-e).

The survey data suggests that quinomethionate is sprayed

more by the growers who consider this problem the second worst pest problem and is usually applied at the beginning of the season, since this a.i. has a harvest interval of 28 days, while triadimefon tends to be applied more by the growers who consider powdery mildew the first pest problem.

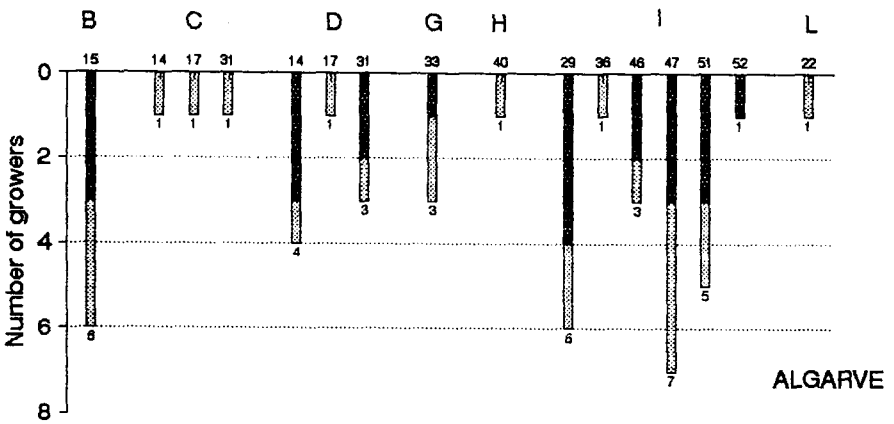


Fig. 5.25 - Pesticides applied by the growers against the worst pest problems in the melon crop

(The pesticide reference is made according to the legend of Fig. 5.24 (page 197))

PEST PROBLEMS - considered the worst pest problem - considered the second worst pest problem

B - Nematodes
C - Soil fungi
D - *Fusarium* wilt
G - Spider mites
H - Whiteflies
I - Powdery mildew
L - Aphids

Two growers also applied nuarimol (a pyrimidine fungicide) and penconazole (a triazole fungicide) against powdery mildew in melon (each a.i. was applied by one grower). Both a.i. were recently cleared by the Portuguese pesticides approval scheme for the control of powdery mildew on vine

(nuarimol in May 1985 and penconazole in October 1986) but not on melon. This fact, again, clearly shows the importance in understanding how growers select the pesticides they apply.

Growers spray on average every 11 days (once or twice every fortnight) if they consider powdery mildew the second worst pest problem, but the interval between sprays is reduced to 6 days when this pest problem is considered the worst one. The decision factors to begin spraying could be "*...15 days after transplanting*"; "*from when the air temperature increases, until the end of May or June...*" or "*...when the plants reach 15-20 cm of height...*".

The majority of the growers apply pesticide at the recommended concentration but 30% of them (3 out of 10) exceeded the concentration by a maximum of 50% .

From the group of growers who consider the cultivar Harvest King particularly sensitive to powdery mildew attack, only one grower (out of 5) indicated the necessity for a more intensive spraying scheme for this cultivar, spraying every four days against this pathogen.

Root-knot nematodes are another important constraint in melon crops in the Algarve (Table 5.19) and they are controlled almost exclusively with fenamiphos (Fig. 5.25) (question no. 14-d1), which is not cleared to be used on the melon crop. Growers apply on average 2.3 applications when root-knot nematodes are regarded as the worst pest problem and 1.3 applications when this pest problem is

considered as the second worst pest problem, and the timing for application has the same pattern discussed above for root-knot nematodes on tomato. All the growers employ the recommended concentration with one exception, belonging to the group which considered root-knot nematodes the worst pest problem, who increased the concentration by 30% (questions nos. 14-d3 and 14-d4). The majority of the growers are planning to apply the same a.i. next season (question no. 14-e).

Spider mites are mainly controlled with the mixture dicofol + tetradifon (Fig. 5.25), two or three treatments being currently applied (question no. 14-d3). The growers who apply quinomethionate against powdery mildew got an additional acaricidal effect from this pesticide.

According to the information presented in Chapter 3.4, growers have been using the same a.i. to control spider mites in the last 3-4 years and they usually employ the recommended concentration (only one grower who considered spider mites the worst pest problem in melon increased the concentration by 15%) (question no. 14-d4).

The worst pest problems indicated by the growers in **green beans** were grey mould and *Fusarium* wilt in the West and grey mould and powdery mildew in the Algarve (Table 5.22).

All the growers in the West apply chemical control against grey mould but in the Algarve two growers (out of 6) did not apply any pesticide against this pathogen (question no.

14-d). The a.i. employed in the West were mainly dicarboximides (vinclozolin, procymidone, iprodione), benzimidazoles (benomyl, carbendazim) and dichlofluanid (Fig. 5.26) while in the Algarve the survey data suggests that growers apply essentially dicarboximides (question no. 14-d1). The majority of these growers are planning to apply the same pesticides next season (question no. 14-e). However, iprodione is the only a.i. cleared to be used in greenhouses against grey mould on green beans. Some growers in the West claimed that vinclozolin, as in the tomato crop, causes flower abortion.

The spraying interval in both regions is 7-8 days (once a week) irrespectively of being the first or second worst pest problem of the crop (question no. 14-d3). Growers begin spraying either when "*...the weather becomes very humid*"; "*when rainy periods begin...*", when "*...disease symptoms are visible...*" or on a phenological basis "*...one week before flowering*"; "*after flowering*"; "*when the plant reaches the top wire of the training system...*".

In the West 5 growers, out of the 9 who considered grey mould the worst pest problem, exceeded the recommended concentration and three of them increased by 100%, while only one grower (out of 4 considering this pest problem the second worst one) exceeded the recommended concentration (a 36% increase). In the Algarve 2 growers (out of 6 who considered this pest problem the worst one in the crop) exceeded the recommended concentration by as much as 25% (question no. 14-d4).

In the West chemical control is employed against *Fusarium* wilt in green beans by some growers (5 out of 8 growers) who considered this pathogen the first or second worst pest problem of the crop.

Thiabendazole seems to be the most applied fungicide but other benzimidazoles (benomyl and carbendazim), thiram and propamocarb hydrochloride are used, applied alternately or in pesticide cocktails (Fig. 5.26). However, these a.i. are not cleared to be applied against this pathogen on green beans. Growers usually made a few pesticide applications (to a maximum of three) in the first phase of the crop cycle, "*...immediately after beans' sowing*"; "*when the first true leaves appear...*" or "*...in the first half of the crop season...*".

Two growers (out of 6) who considered *Fusarium* wilt the worst pest problem in green beans exceeded the recommended concentration by 75% (questions nos. 14-d3 and 14-d4). One grower who tried a pesticide cocktail of benomyl, iprodione and propamocarb hydrochloride in the past got very poor results and is not employing chemical control anymore against this pathogen (question no. 14-f).

Powdery mildew in the Algarve is mainly controlled with triadimefon and fenarimol (Fig. 5.26), which is in agreement with the data collected by Zettelmeyer & Henriques (1986) discussed in Chapter 3.4, and shows that in the Algarve growers have been using the same a.i. against powdery mildew in green beans for the last 3-4

years. However, neither a.i. is cleared to be used on green beans. The number of spray applications through the season is on average 5 with an interval of two weeks between each one (question no. 14-d3).

Both growers who considered powdery mildew in green beans the second worst pest problem in the crop exceeded the recommended concentration by 25% (question no. 14-d4).

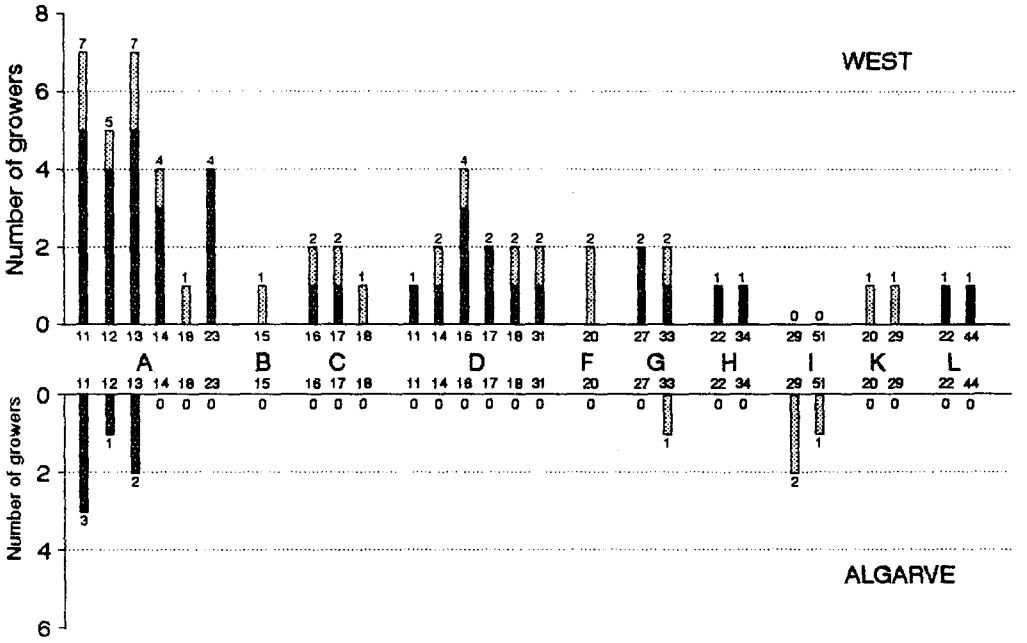


Fig. 5.26 - Pesticides applied by the growers against the worst pest problems in the green bean crop

(The pesticide reference is made according to the legend of Fig. 5.24 (page 197))

PEST PROBLEMS - considered the worst pest problem - considered the second worst pest problem

A - Grey mould
B - Nematodes
C - Soil fungi
D - *Fusarium* wilt
F - Blight
G - Spider mites
H - Whiteflies
I - Powdery mildew
K - Rust
L - Aphids

To control spider mites in green beans the growers employ cyhexatin and the mixture dicofol + tetradifon (Fig. 5.26). In the West, when this problem is considered the worst pest problem of the crop (two growers), one or two treatments per fortnight are necessary while two sprays seem to solve the problem when this pest is considered the second worst pest problem (1 grower) (question no. 14-d3).

Spraying begins "*...after the fruit set*"; "*after April...*" or "*...in the beginning of the crop season...*". Cyhexatin is always applied late in the season when spider mites are more abundant, but this behaviour can cause residue problems (the recommended harvest interval for cyhexatin on green beans is 28 days). All the growers spray the recommended concentration (question no. 14-d4).

Powdery mildew was one of the worst pest problems pointed out on sweet pepper in the Algarve. Dinocap and triadimefon were the a.i. employed by one grower, through the season, to control the pathogen (Fig. 5.27). Treatments were applied once a fortnight, beginning 20 days after transplanting, and the grower exceeded the recommended concentration by 25% (questions nos. 14-d1, 14--d3 and 14-d4). The grower is planning to apply the same control method if he is confronted with the same pest problem in the crop (question no. 14-e).

Pepper blight was another worst pest problem indicated for the crop by one grower, and mancozeb or propineb in mixture

with cymoxanil were sprayed (Fig. 5.27) every week, during rainy periods, or every fortnight, beginning two weeks after transplanting.

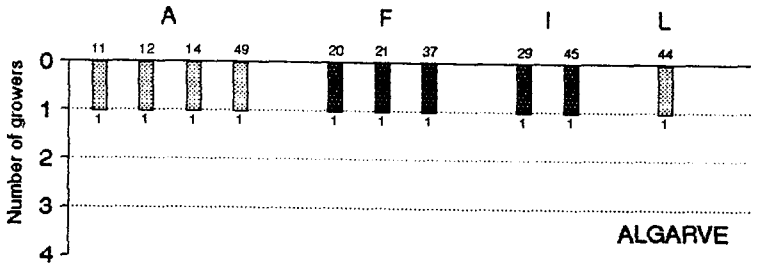


Fig. 5.27 - Pesticides applied by the growers against the worst pest problems in the sweet pepper crop

(The pesticide reference is made according to the legend of Fig. 5.24 (page 197))

PEST PROBLEMS - considered the worst pest problem - considered the second worst pest problem

A - Grey mould

F - Blight

I - Powdery mildew

L - Aphids

On lettuce the disease complex *Sclerotinia* disease/grey mould was indicated as the worst pest problem of the crop in the West by two growers. They employed dicarboximides (iprodione and vinclozolin) as well as benomyl and dichlofluanid to control the pathogens, sprayed every seven days on average (question no. 14-d3), starting at transplanting. However, dicarboximides are not cleared to be used against grey mould on lettuce. Both growers

exceeded the recommended concentration (question no. 14--d4), one of them by 100%.

The other worst pest problem pointed out for lettuce by 1 grower was cutworms. To control them the grower applied parathion, formulated as a wettable powder, and spread the powder along the line of the plants (question no. 14-d1).

On **cucumber** only powdery mildew was pointed out as the worst pest problem on the crop, by one grower. This pathogen was controlled by two applications of triadimefon during the final phase of the crop (questions nos. 14-d1 and 14-d3). The grower exceeded the recommended concentration by 50% (question no. 14-d4) and was planning to use the same control method next season (question no. 14-e).

In order to clarify better how growers solve **soil pest problems**, if not considered amongst the worst ones, question no. 17 was used. The a.i. pointed out by the growers are represented in Fig. 5.28. In the West only 4 growers (out of 32) and in the Algarve 2 growers (out of 29) did not apply pesticides against soil pest problems.

In the West fenamiphos is the most applied pesticide in the soil (11 growers) followed by propamocarb hydrochloride (9), thiram (8), benomyl (6) and lindane (5). Such frequency suggests that nematodes and soil-borne fungi (like *Phytophthora, Pythium, Verticillium* or *Fusarium*

species) are the most important soil pest problems while insects only occasionally cause trouble. By contrast, in the Algarve chlorpyrifos (13 growers), fenamiphos (7), benomyl (6), propamocarb hydrochloride and aldrin (5) and dazomet and thiram (4) are the most applied pesticides in the soil. Insect soil pests, particularly wireworms (*Agriotes* spp.) seem to be regarded as the most frequent soil pest problem, with nematodes and soil-borne fungi not being such a widespread pest problem as soil insects.

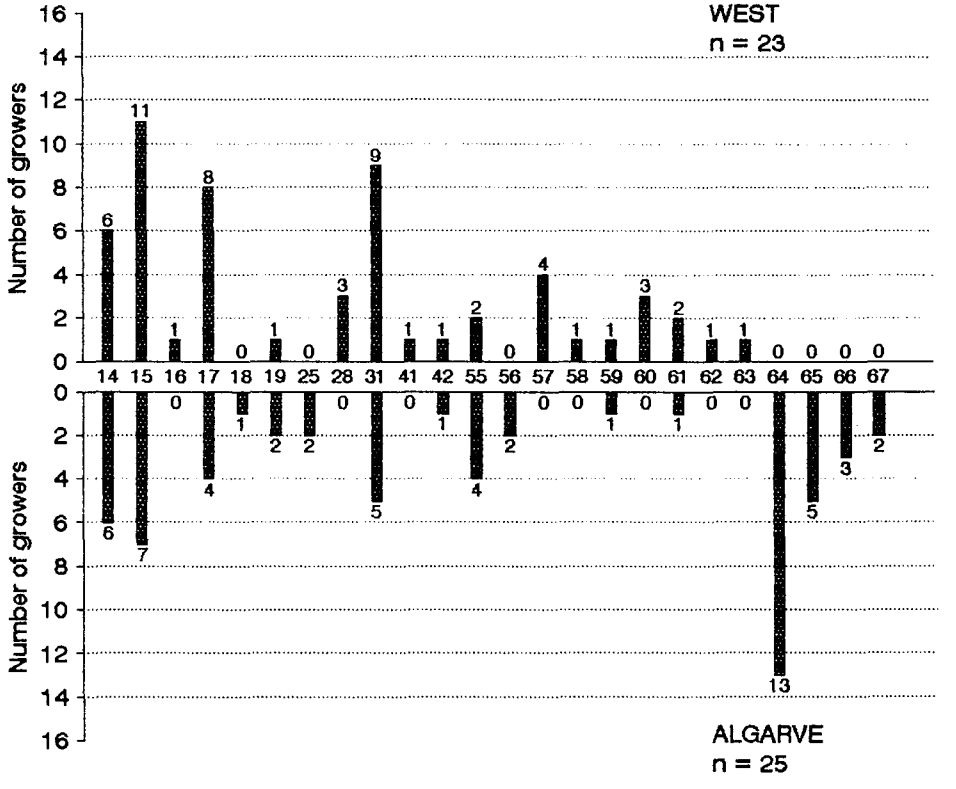


Fig. 5.28 - Pesticides employed by the growers to control soil pest problems

(The pesticide reference is made according to the legend of Fig. 5.24 (page 197))

A few growers are trying to control *Fusarium* species by applying the antibiotic polyoxin (a B-rich mixture) in the soil. This antibiotic is produced by *Streptomyces cacaoi*

var. *asoensis*, inhibits the synthesis of cell-wall chitin of some fungi (Misato *et al.*, 1977; Misato, 1984), and is effective against *Alternaria* spp., *Botrytis cinerea* and *Erysiphaceae* (Worthing, 1987). Clearly, this is another situation where growers are applying pesticides by trial and error and, again, the selling and application of this pesticide is not allowed in Portugal but the growers obtain it illegally.

The majority of the growers in both regions spray their seedlings regularly during the **nursery period** (question no. 18).

For **tomato** transplants 20 growers in each of the regions apply, on average, 3 treatments during the nursery period in both of the areas. However, one grower in the Algarve who also runs a commercial nursery sprays three times more than the average for the region. This fact could mean that the quality standards achieved by commercial nurseries are based on very intensive spraying schemes and, if it is the case, the growers must be aware of the potential threat placed by dissemination of pathogens and arthropod pests resistant to commonly used pesticides through these transplant suppliers in the near future.

The most applied a.i. in the West are mancozeb (11 growers), propamocarb hydrochloride (7), thiram (5), benomyl (4) and cymoxanil (3); in the Algarve mancozeb (10 growers), cymoxanil (5), propineb (4) and benomyl and deltamethrin (3 each) are the most applied pesticides (Fig.

5.29).

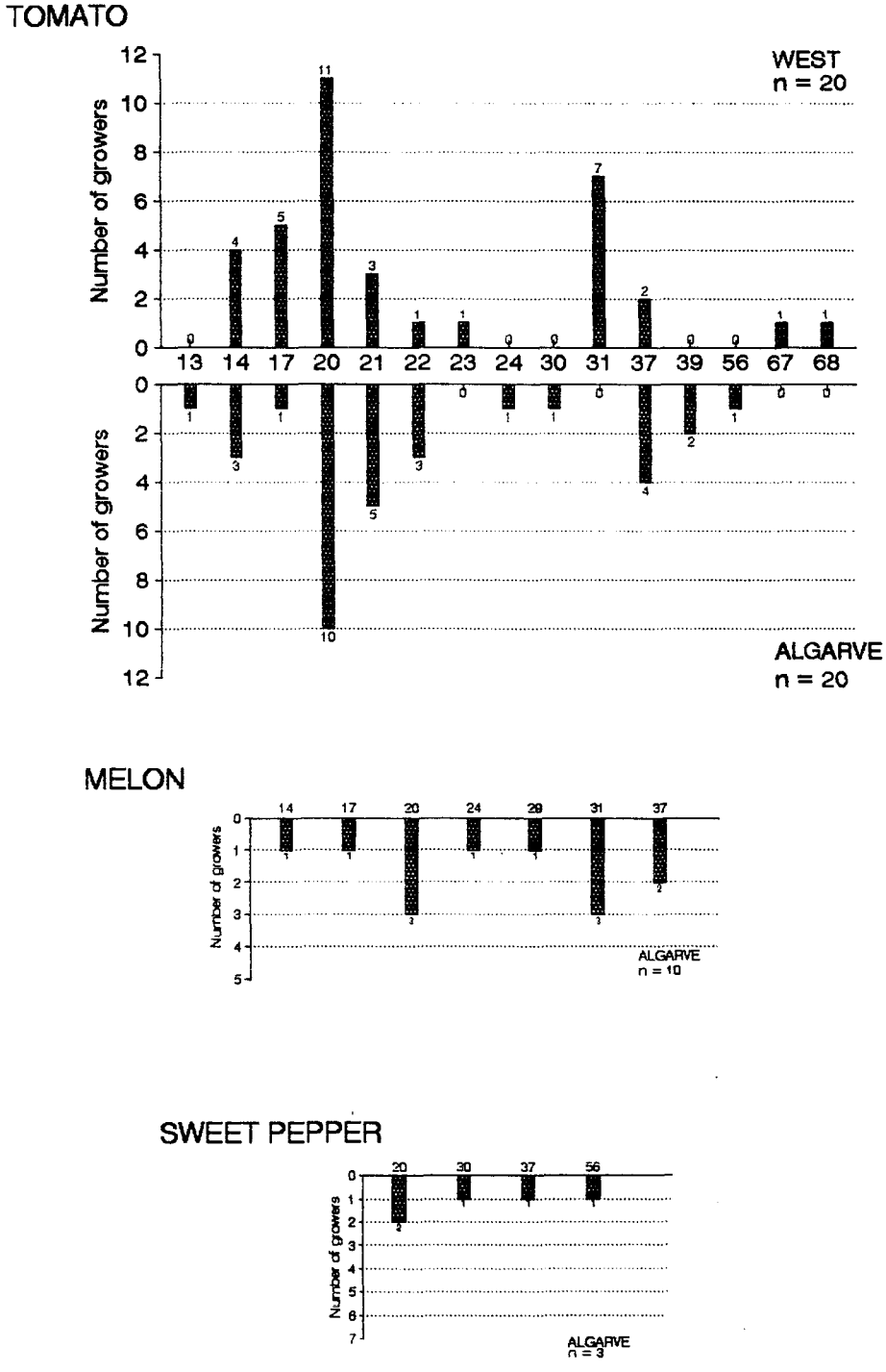


Fig. 5.29 - Pesticides used in the nurseries

(The pesticide reference is made according to the legend of Fig. 5.24 (page 197))

Concerning other crops, the survey data only provided some information for melon (10 growers) and sweet pepper (3 growers) in the Algarve. In both cases growers apply an average of 3 treatments during the nursery period.

The most applied a.i. in **melon** transplants seem to be propamocarb hydrochloride (3 growers), mancozeb (3) and propineb (2), while in **sweet pepper** transplants mancozeb (2 growers) seems to be the most applied a.i. (Fig. 5.29).

5.3.6.5 - Pesticide application

There are differences between both regions respecting the pesticide application methods adopted by the growers.

Concerning pesticide applications to the aerial parts of the crops (question no. 15), the most common procedure in the West consists of applying the two or three first treatments with a hydraulic knapsack sprayer and then changing to a knapsack mistblower for the later part of the season (50% (16/32) of the growers have this behaviour) while 10 growers use the knapsack mistblower throughout the season for every treatment. In this region the knapsack mistblower is employed by 84% (27/32) of the growers, the hydraulic knapsack sprayer by 56% (18/32) and the tractor--mounted sprayer by 16% (5/32) of the growers (Fig. 5.30).

In the Algarve 79% (23/29) of the growers employed tractor--mounted sprayers while knapsack mistblowers are employed

by 17% (5/29) and hydraulic knapsack sprayers by 21% (6/29) of them (Fig. 5.30). In this region 83% (24/29) of the growers employed the same spraying equipment from transplanting to the end of the crop season and 69% (20/29) of them spray with tractor-mounted sprayers.

Concerning the application of pesticides in the soil (question no. 15), the most common procedure in the West (19 growers out of 22 who answered this question) consists of applying them through the irrigation system (particularly for the application of nematicides (17 growers indicated their application and 2 growers pointed out the application of fungicides against soil-borne fungi)), while 3 growers incorporated pesticides in the soil mechanically (with a harrow or rotary cultivator) and two other growers spread pesticides over the soil along the line of the plants and then incorporated them with water (Fig. 5.30).

In the Algarve the incorporation of pesticides in the soil mechanically (with a harrow or rotary cultivator) is the most common application method (14 growers out of 20 who answered this question), particularly adopted for insecticide applications. Application through the irrigation system is the second most adopted (11 growers), especially employed with nematicides (Fig. 5.30). Both of these techniques are employed simultaneously by 7 growers.

It should be stressed that most insecticides used in the soil in the Algarve (chlorpyrifos, aldrin and dazomet (as

indicated in 5.3.6.4)) are all formulated in granules, which possibly justifies the growers preference. However, concerning nematicides and especially fenamiphos, the growers clearly prefer the emulsifiable concentrate (e.c.) formulation in both regions, since this a.i. is available on the Portuguese market in e.c. and granules formulations. By contrast fungicides employed in the soil are formulated as aqueous solution (propamocarb hydrochloride) or wettable powder (benomyl and thiram).

In the nurseries (questions no. 15 and 18) growers apply pesticides mainly with hydraulic knapsack sprayers in both regions (8 growers in the West and 9 in the Algarve (Fig. 5.30)). However, some growers in the West use knapsack mistblowers to apply pesticides even in the nurseries (3 growers out of 11 who gave information on this topic) while in the Algarve tractor-mounted sprayers (3 growers out of 12 who gave information on this topic), knapsack mistblowers (1 grower) and fumigation of the nursery (1 grower) were also reported by the growers as ways to apply pesticides in their nurseries (Fig. 5.30).

It is worth mentioning the fact that some growers in the West and a few in the Algarve have fogging machines or are planning to buy them in the near future, following the recent introduction of thermal pulsejet fogging equipment (PULSFOG ^{R}) in the Portuguese market.

The major attractions mentioned by the growers for this

equipment are the considerable savings in time and labour, when compared with the normal high-volume sprays. However, no grower was worried by the fact that greenhouses need to be almost completely airtight to obtain an even pesticide distribution, otherwise the fog can became very unevenly distributed inside the greenhouse or even be sucked out very rapidly through leakages, under windy conditions (Robinson & Wilson, 1979). Bearing in mind the characteristics of the plastic greenhouses commonly adopted in Portugal such conditions seem difficult to achieve and as a result, uneven distribution of pesticide within the crop should be expected.

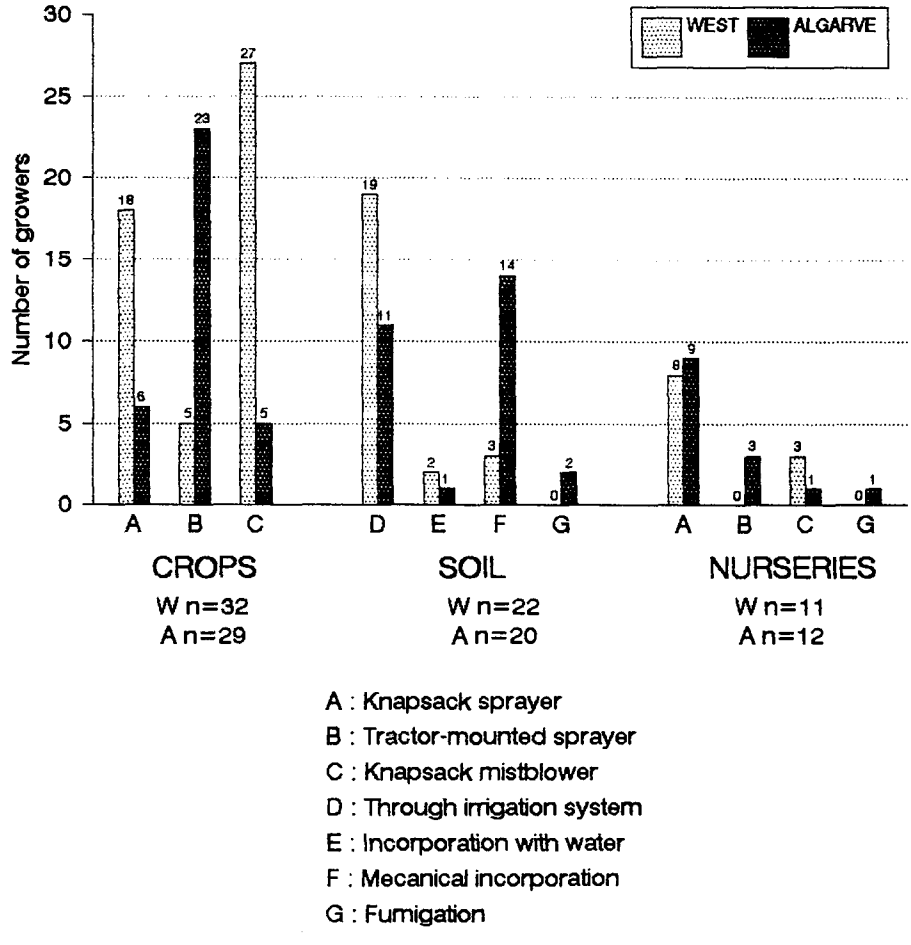


Fig. 5.30 - Pesticide application methods

Furthermore, pesticides applied with this method generally only cover the upper side of the leaves with very little pesticide being deposited on the under-side of the leaves. This result has been consistently achieved by several researchers using different pesticides (fungicides like dichlofluanid and iprodione (Morgan & Spencer, 1978; Morgan, 1979a); insecticides like resmethrin (Munthali, 1976) and *Bacillus thuringiensis* (Jarrett *et al.*, 1978); acaricides like fenbutatin-oxide (Lindquist & Powell, 1980)). This drawback seems to be especially important for some arthropod pests in greenhouses (whiteflies, spider mites, thrips, caterpillars from several species, which hide themselves mainly on the under-side of the leaves), while satisfactory results were achieved against grey mould in tomato (Morgan, 1979a; Robinson & Wilson, 1979), particularly when the fungicide was formulated specifically for fogging applications.

Since in Portugal there are no approved a.i. specifically formulated for thermal fogging application, growers choosing this application method must rely on special additives to improve fogging characteristics. However, these additives (like PULSFOG ^{R} "VK-2 special" carrier solvent) have not yet been cleared by the Portuguese pesticides approval scheme .

This is another situation where growers are being innovative, despite a lack of relevant technical information.

5.3.7 - Growers' attitude to other control methods

Apart from chemical control, which is the major control method employed in greenhouses (5.3.6.4), growers were also asked about other control methods widely used in other countries. This allowed an assessment of growers' attitudes to these techniques and gave an understanding about their future use.

5.3.7.1 - Biological control

Biological control is a well established control method in greenhouses, as described in Chapter 2 and table B in appendix I.

The results of question no. 37, intended to clarify the growers' attitude to this technique, are presented in Table 5.28.

Table 5.28 - Growers' attitude towards biological control

\ Attitude to biol. control / Region \	A	B	C	D
WEST	15(*)	13	4	0
ALGARVE	11	13	5	0

Attitude scale:

A - Do not know / Never heard about it
B - Heard about it but sceptical or do not accept the idea
C - Heard about it and accept it / consider it a good idea
D - Are going to apply it or have already applied it

(*) - Number of growers who gave this answer

In both areas growers have the same attitude to biological control ($X^2_{[2]}$ = 0.58 (n.s.)) and the idea of biological control, at present and for the majority of the growers, either is completely unknown (47% of the surveyed growers in the West and 38% in the Algarve) or the concept is considered not acceptable by the growers (40% in the West and 45% in the Algarve). Those who accept the idea (13% in the West and 17% in the Algarve), because they are the potential innovators of this control method, should be the target for any attempt to introduce biological control practices in Portuguese greenhouses.

According to Hussey (1984), in the U.K. growers were also incredulous at first but their confidence in this control method increased gradually with experience.

Clearly, an information gap about biological control exists in Portugal. Any research programme on this subject in the country can profit from experiments in other Mediterranean countries (Spain, Italy, Greece). Such research would need to be strongly linked with an extension effort if any practical achievement is expected.

5.3.7.2 - Solarization

Solarization, as discussed in Chapter 2, is a relatively recent approach to control some of the soil-pest problems, with good prospects in the Mediterranean region.

When the growers were asked about this technique (question

no. 38), the pattern of answers varied according to the region (Table 5.29).

In the West 75% of the surveyed growers do not have any information about this technique (44%) or if they have they are sceptical about the results (31%), while in the Algarve 41% of the surveyed growers think this is a good idea (31%) or have already applied this technique (10%). This significant difference between the regions ($X^2_{[2]}$ = 6.62 (p.< 0.05)) is possibly due to the research and extension effort by the regional services of the Ministry of Agriculture in the Algarve in the recent past, while in the West research on the subject is only beginning.

Table 5.29 - Growers' attitude towards solarization

\ Attitude to solarization / Region \	A	B	C	D
WEST	14(*)	10	8	0
ALGARVE	4	13	9	3

Attitude scale:

A - Do not know / Never heard about it
B - Heard about it but sceptical or do not accept the idea
C - Heard about it and accept it / consider it a good idea
D - Are going to apply it or have already applied it

(*) - Number of growers who gave this answer

It is worth mentioning that in the Algarve several growers stated that it would be possible to stop production in the summer between two consecutive crops for 4-6 weeks (the period necessary to achieve good results with this method)

without major economic disadvantages; by contrast in the West the growers claimed that a delay of 6 weeks between two consecutive crops in the summer would result in economic disadvantages which need to be considered.

Some growers in the Algarve fear that this method could reduce the life of greenhouse plastics, especially if greenhouses are kept completely closed during this process in order to raise the inside temperature. Some experiments done in the south of France recorded air temperatures inside closed plastic greenhouses under solarization of 50--55° C for several hours per day, which can be incompatible with the resistance characteristics of the plastic (Goisque *et al.*, 1984). Temperatures of this magnitude (55° C) were also recorded inside greenhouses in Portugal when they were closed without ventilation (Silva & Rosa, 1985).

The comparison between the attitude of the Algarve growers to this control method and to biological control reveals a significant difference between them ($X^2_{[2]}$ = 6.15 ($p.<0.05$)), as a result of the diffusion of the solarization technique among innovative growers, while in the West growers regard solarization as well as biological control with the same attitude ($X^2_{[2]}$ = 1.76 (n.s.)).

5.3.7.3 - Resistant cultivars

Question no. 39 was intended to establish if growers regard the use of resistant cultivars as an alternative control

method against pest problems. From the results (Table 5.30) it became evident that more than half of the surveyed growers do not use resistant cultivars as a control method (56% of the surveyed growers in the West and 52% in the Algarve) and the pattern for use of resistant cultivars is the same in both regions ($X^2_{[2]} = 0.13$ (n.s.)).

Several growers in both regions belonging to the group which does not grow resistant cultivars indicated that the decision factors to select a cultivar were their productivity and acceptability by the market.

Table 5.30 - Growers' attitude towards resistant cultivars

Region \ Attitude to resistant cultivars	I	II
WEST	18(*)	14
ALGARVE	15	14

Attitude scale:

I - Do not grow resistant cultivars as a control method
II - Grow resistant cultivars as a control method

(*) - Number of growers who gave this answer

5.3.8 - Growers' assessment of pests, controls and available technical information

5.3.8.1 - Assessment of pest problems

Growers in the West seem to be more worried about the threat of potential losses caused by pests than with the costs of control or the amount of time spent applying control methods (Fig. 5.31). By contrast in the Algarve the high costs of pesticides and application methods seem to be the most important points for the growers, with concern for potential losses and time consumption by crop protection coming next (Fig. 5.31). In both regions the occurrence of high losses is sometimes regarded as the most important problem and toxicological problems for the pesticides applicator are seldom indicated (Fig. 5.31) (question no. 16).

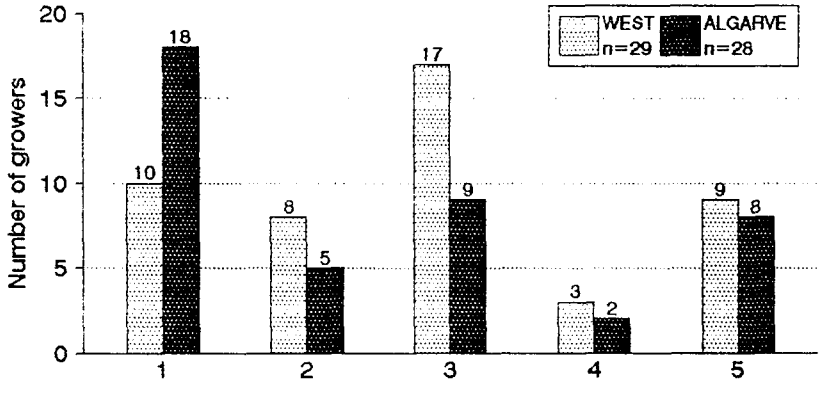


Fig. 5.31 - Growers' perception of problems related to crop protection

Crop protection problems: 1 - High costs of pesticides and application methods
2 - Occurrence of high losses
3 - Concern caused by potential losses
4 - Pesticides toxicity to field workers
5 - Plant protection is very time consuming and the grower needs to be very attentive

Pest problems are detected mainly through visual inspection of the crop (21 growers in the West and 24 in the Algarve). Detection of pest problems during technical work in the greenhouse is not so frequent (11 growers in the West and 5 in the Algarve). No growers ignore pest problems until they see their symptoms (question no. 19).

Crop monitoring presents a bimodal pattern with the majority of growers doing visual inspections daily, normally early in the morning when they open the greenhouse windows or late in the afternoon when they close them. The second modal frequency employed by some growers to perform visual inspections is a weekly time period, with very few growers doing 2 or 3 visual inspections per week (Fig. 5.32).

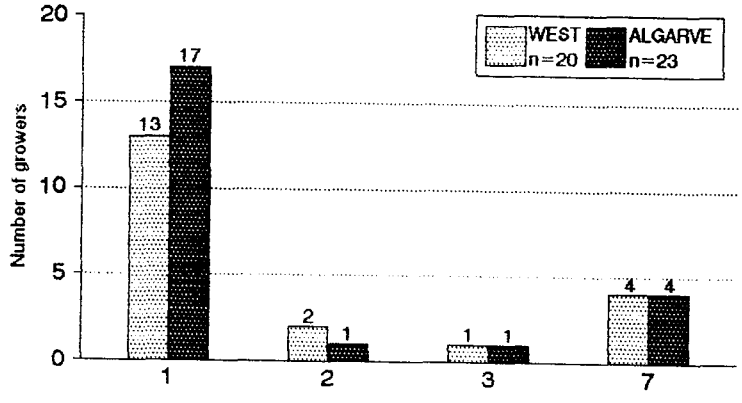


Fig. 5.32 - Frequency of crop monitoring for pest problems

1 .. 2 .. 3 .. 7 .. - Number of days between two consecutive visual inspections

The average pest incidence levels (% of affected plants) perceived by the growers for the major pest problems are

presented in Table 5.31 (question no. 14-i).

Table 5.31 - Average infestation level of major pest problems perceived by the growers

CROP	PEST PROBLEM	REGION	When considered the first problem		When considered the second problem	
			Pest incidence (%)	No of growers indicating infestation/No of growers indicating the problem	Pest incidence (%)	No of growers indicating infestation/No of growers indicating the problem
	GREY MOULD	West	36	16/19	50	2/7
		Algarve	20	10/20	42	2/5
	LATE BLIGHT	West	64	2/6	18	2/11
		Algarve	0	1/2	5	2/11
T	SPIDER MITES	West			?	1/1
O		Algarve			50	2/5
M	CATER-PILLARS	West			3	4/5
A		Algarve			?	1/1
T	NEMATO-DES	West	?	2/2	50	1/2
O		Algarve	86	3/6	100	1/1
	WHITEFLY	West	?	1/1		
		Algarve	100	1/1	?	1/1
	POWDERY MILDEW	West	70	1/2	?	1/1
	BACTERIA	West	?	2/2	?	1/1
M	*Fusarium*	Algarve	63	6/10	31	4/4
E	POWDERY MILDEW	Algarve	30	2/5	?	3/5
L	NEMATODES	Algarve	72	2/3	50	1/3
O	SPIDER MITES	Algarve	?	1/1	?	2/2
N						

Table 5.31 - (cont.)

CROP	PEST PROBLEM	REGION	When considered the first problem		When considered the second problem	
			Pest incidence (%)	No of growers indicating infestation/No of growers indicating the problem	Pest incidence (%)	No of growers indicating infestation/No of growers indicating the problem
	GREY MOULD	West	42	5/9	25	1/4
GRAPE		Algarve	25	1/6		
BEAN	*Fusarium*	West	40	2/6	?	2/2
	POWDERY MILDEW	Algarve			?	2/2
	POWDERY MILDEW	Algarve	?	1/1		
SWEET PEPPER	BLIGHT	Algarve	?	1/1		
	VIRUSES	Algarve	8	1/1		
	APHIDS	Algarve			?	1/1
CUCUMBER	POWDERY MILDEW	West	?	1/1		
LETTUCE	*Sclerotinia*/GREY MOULD	West	50	1/2		
	CUTWORMS	West	?	1/1		

Pest problems in general are regarded as an increasing problem in the Algarve (78% of the surveyed growers answering question no. 21) while in the West the majority of the growers (52%) indicated that pest problems are staying the same. Very few growers consider that pest problems have decreased in importance (Table 5.32).

This significant difference between the regions on the growers' perceptions of pest problems in the recent past ($X^2_{[2]}$ = 11.71 (p.< 0.01)) is probably due to historical reasons linked with the development of this activity in each of the regions, previously discussed in Chapters 3 and 5.3.5.

Table 5.32 - Growers' perspectives of pest problems during the last few years

Region \ Perspective of pest problems during last few years	i	ii	iii
WEST	12(*)	16	3
ALGARVE	22	3	3

Perspective of pest problems in the last few years:

i - increasing in importance
ii - staying the same
iii - decreasing in importance

(*) - Number of growers who gave this answer

However, this increasing importance is not caused by any recent widespread failure in controlling any particular major pest (question no. 26). All the pest problems where growers faced recent difficulties obtaining good control are on the tomato crop, with the exception of spider mites on green beans, in the West. These pest problems (Fig. 5.33) are the predominant ones on the tomato crop,

including late blight, caterpillars, grey mould, powdery mildew (see 5.3.6.2) and the difficulties controlling them probably result from a particular bad season suitable for the pest, and/or control methods not accurately applied. Only one grower in the Algarve claimed that grey mould problems in tomato are linked with a reduction in efficacy of the fungicide vinclozolin, suggesting possible resistance.

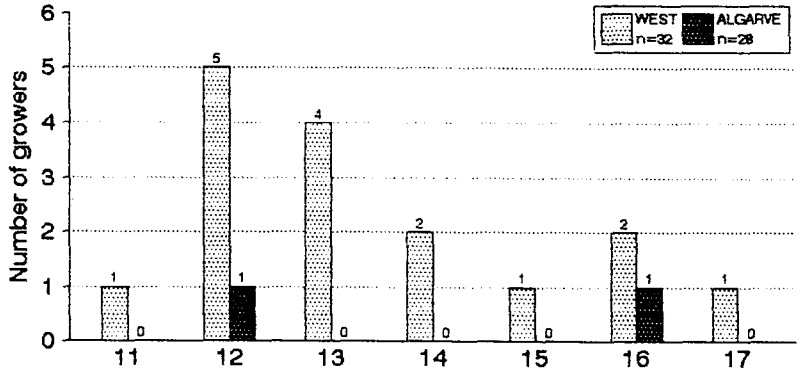


Fig. 5.33 - Pest problems where growers faced recent difficulties achieving good control

11 - bacteria
12 - late blight
13 - caterpillars
14 - powdery mildew
15 - whiteflies
16 - grey mould
17 - spider mites

Some pest problems are perceived by some growers as problems against which no satisfactory control was ever achieved (question no. 27) or is often difficult to obtain.

On the <u>tomato</u> crop, grey mould is regarded as the most troublesome disease in both regions. Bacteria are another disease problem reported in the West on tomato with several control failures (6 growers out of 31 who answered this question) (Fig. 5.34). In the Algarve failure in the

control of nematodes was also reported by some growers (3 out of 28).

On **melon**, *Fusarium* wilt is regarded as a very difficult disease to control in the Algarve. This disease was indicated by the majority of the growers in this region (19 growers out of 28), and is the most prevalent case of control failure detected in this study (Fig. 5.34).

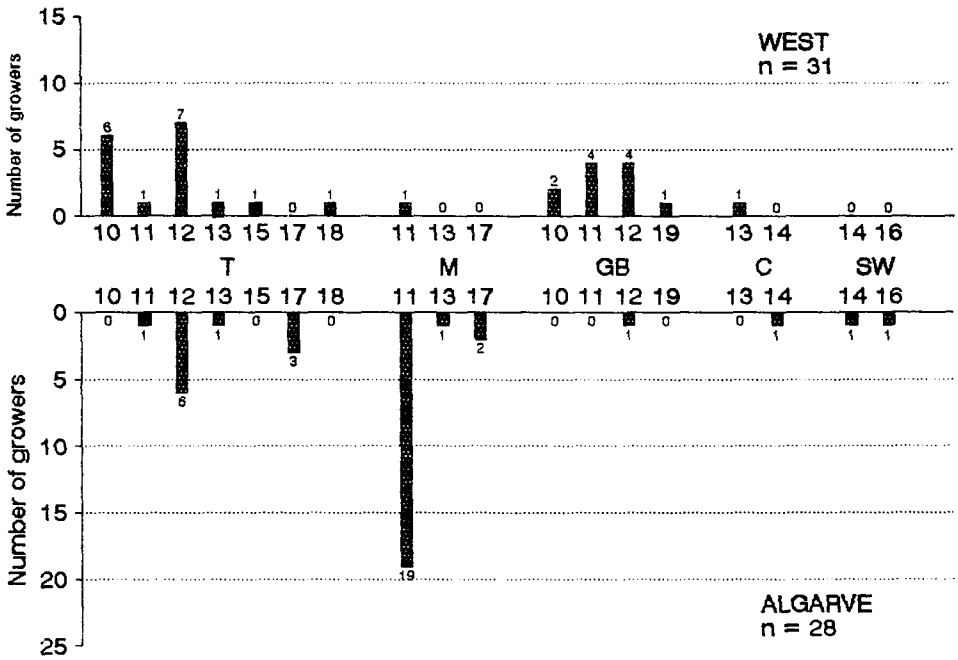


Fig. 5.34 - Pest problems where growers never achieved good control

10 - bacteria
11 - *Fusarium* wilt
12 - grey mould
13 - late blight / downy mildew
14 - powdery mildew
15 - leaf mould
16 - viruses
17 - nematodes
18 - caterpillars
19 - spider mites

T - tomato M - melon GB - green beans C - cucumber SW - sweet pepper

For **green beans**, grey mould and *Fusarium* wilt were the diseases pointed out by the growers in the West as those presenting more cases of control failure. Other pest problems indicated in the West were bacteria and spider

mites, while in the Algarve only one grower indicated poor control of grey mould on this crop (Fig. 5.34).

For **cucumber** and **sweet pepper** only a few pest problems such as powdery mildew were indicated and each one only by one grower, which suggests that on these crops growers do not face as many difficult control problems as in other major crops like tomato.

5.3.8.2 - Assessment of control methods

The survey results concerning the growers' expectations of the benefits they would achieve if they spent more time inspecting greenhouse crops (question no. 20) suggest that there is no significant difference between the regions ($X^2_{[1]}$ = 1.29 (n.s.)). However, in the West 13 growers (out of 32) would expect more benefits while in the Algarve 16 growers (out of 29) would expect more benefits if they spent more time on monitoring activities on the crops (Table 5.33).

This perception of the benefits of monitoring is independent of the inspection strategy adopted by each grower and discussed in the previous section. However, when the growers were asked if they could spend more time inspecting the crops (question no. 20), the majority of them claimed that they could not (27 growers in each of the regions). Only 5 growers in the West and 2 in the Algarve indicated that they could dedicate more time to monitoring activities but all but one in each region did not expect

additional benefits from this activity; the exception in the Algarve was a young grower just at the end of the first year of business and the exception in the West was a very experienced grower who agreed in principle with the idea of spending as much time as possible monitoring the crops. However, in his particular case he was not sure if he would have any benefit because of his long experience (13 years).

Table 5.33 - Growers' assessment of benefits resulting from more time inspecting the crops

Assessment of additional inspection of crops / Region	I	II
WEST	19(*)	13
ALGARVE	13	16

Assessment scale:

I - No benefits resulting from additional crop inspection
II - Benefits resulting from additional crop inspection

(*) - Number of growers who gave this answer

From these results it seems that any attempt to develop pest control strategies involving much more monitoring time than is currently practised will be difficult to accept by growers, since the majority claimed that they can not spend more time on this activity. Furthermore, those who can do not expect any additional benefit from this activity at the moment.

Pesticides employed to control pest problems are considered

efficient in general by the growers, since 71% (22/31) of them in the West and 79% (23/29) in the Algarve were happy with the efficacy of pesticides (question no. 28). Those who claimed not to be happy with pesticide efficacy in general had experienced some poor pest control in the past or perceived pesticide efficacy changing from product to product. Concerning price, pesticides are almost always regarded as expensive or very expensive production factors (Table 5.34).

Table 5.34 - Growers' assessment of pesticide prices

Assessment of pestic. prices / Region	A	B	C	D
WEST	15(*)	12	3	0
ALGARVE	13	16	0	0

Pesticide prices' scale:

A - Very expensive
B - Expensive
C - Reasonable
D - Cheap

(*) - Number of growers who gave this answer

Growers are usually satisfied with the efficacy of the application methods employed (81% in the West and 86% in the Algarve indicated "*Yes*" in question no. 29). Those growers who are not happy with the application methods (6 in the West and 4 in the Algarve) pointed out several reasons for their dissatisfaction, like: "*...bad results achieved with the knapsack mistblower and slow work with the hydraulic knapsack sprayer*"; "*spraying introduces too*

much water inside greenhouses"; "waste of pesticide caused by run-off"; "high labour requirements"; "sprayers lose calibration and technical characteristics easily, linked with lack of technical assistance"; "lack of better application machinery on the market..."

Application costs are generally considered reasonable (Table 5.35). However, a considerable number of growers indicated the application costs as high or very high, especially in the West (Table 5.35).

Table 5.35 - Growers' assessment of application costs

\ Assessment of applicat. costs / Region \	A	B	C	D
WEST	8(*)	8	16	0
ALGARVE	1	11	17	0

Application costs' scale:

A - Extremely high
B - High
C - Reasonable
D - Low

(*) - Number of growers who gave this answer

How is the assessment of efficacy related to pesticides and application methods, discussed above in general terms, translated when particular pest problems are considered ? Table 5.36 indicates the benefits, in terms of crop loss reduction (column (B-A)), expected by the surveyed growers, when they apply the control methods commonly used (questions no. 14-g and 14-h).

Table 5.36 - Average crop losses perceived by the growers to major pest problems with and without the control methods employed

CROP	PEST PROBLEM	REGION	When considered the first problem					When considered the second problem				
			A	R	B	R	B-A	A	R	B	R	B-A
TOMATO	GREY MOULD	West	11	11/19	73	13/19	62	1	4/7	100	1/7	99
		Algarve	26	15/20	78	11/20	52	21	4/5	58	3/5	37
	LATE BLIGHT	West	28	5/6	100	2/6	72	12	7/11	84	7/11	72
		Algarve	?	2/2	?	2/2	?	6	5/11	100	4/11	94
	SPIDER MITES	West						0	1/1	50	1/1	50
		Algarve						12	2/5	?	5/5	?
	CATER-PILLARS	West						1	3/5	75	2/5	74
		Algarve						0	1/1	100	1/1	100
	NEMATO-DES	West	50	1/2	100	1/2	50	19	2/2	100	2/2	81
		Algarve	52	2/6	100	2/6	48	50	1/1	?	1/1	?
	WHITEFLY	West	28	1/1	90	1/1	62					
		Algarve	0	1/1	?	1/1	?	25	1/1	50	1/1	25
	POWDERY MILDEW	West	20	1/2	70	1/2	50	0	1/1	?	1/1	?
	BACTERIA	West	30	2/2	?	2/2	?	100	1/1	100	1/1	0
MELON	*Fusarium*	Algarve	54	7/10	69	7/10	15	31	4/4	?	4/4	?
	POWDERY MILDEW	Algarve	17	3/5	100	3/5	83	0	3/5	75	2/5	75
	NEMATODES	Algarve	52	2/3	100	1/3	48	35	1/3	50	1/3	15
	SPIDER MITES	Algarve	?	1/1	?	1/1	?	25	1/2	?	2/2	?

Table 5.36 - (cont.)

CROP	PEST PROBLEM	REGION	When considered the first problem					When considered the second problem				
			A	R	B	R	B-A	A	R	B	R	B-A
		West	14	5/9	46	6/9	32	7	4/4	80	3/4	73
	GREY	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
G B	MOULD	Algarve	17	4/6	62	2/6	45					
R E												
E A	*Fusarium*	West	60	3/6	100	1/6	40	?	2/2	?	2/2	?
E N												
N S	POWDERY MILDEW	Algarve						10	1/2	25	1/2	15
	POWDERY MILDEW	Algarve	0	1/1	40	1/1	40					
S P												
W B	BLIGHT	Algarve	?	1/1	?	1/1	?					
E P												
E P	VIRUSES	Algarve	50	1/1	?	1/1	?					
T E												
R	APHIDS	Algarve						0	1/1	100	1/1	100
	POWDERY MILDEW	West	30	1/1	50	1/1	20					
CUCUMBER												
	Sclerotinia/GREY MOULD	West	25	2/2	75	2/2	50					
LETTUCE												
	CUTWORMS	West	10	1/1	100	1/1	90					

A : Growers' perception of crop losses caused by the pest problem after application of control methods (%)
B : Growers' perception of crop losses caused by the pest problem without application of control methods (%)
R : Number of growers indicating crop losses value / number of growers indicating the pest problem
B-A : Growers' perception of the results achieved with control methods adopted against the pest problem (%)

For the majority of the growers in both regions the timing of harvest is not affected by the application of pesticides (question no. 30). All those who consider that timing of harvest is affected (Table 5.37) mentioned difficulties with the harvest interval (H.I.) officially recommended,

particularly during the period when harvesting occurs simultaneously with vegetative growth of the plants and development of the new fruit, which is the case with the majority of greenhouse crops.

Table 5.37 - Growers' assessment of the effect of pesticide applications on the timing of harvest

\Assess. of effect \of pest. applic. \on timing harv. / Region \	I	II
WEST	18(*)	13
ALGARVE	19	10

Assessment scale:

I - No effect
II - Effect

(*) - Number of growers who gave this answer

($X^2_{[1]} = 0.35$ (n.s.))

Growers pick tomatoes twice or three times a week, melons every two days and green beans at least twice a week. Under these conditions it is very difficult to observe the harvest intervals, bearing in mind the pesticides employed by the growers and their spraying strategies (see 5.3.6.4), since just a few pesticides amongst those cleared for greenhouse crops have a harvest interval shorter than 7 days. (The exceptions amongst the pesticides employed by the surveyed growers are: the fungicides vinclozolin (on sweet pepper, cucumber, green beans and tomato crops - 3 days H.I.), benomyl (on tomato - 4 days H.I.),

dichlofluanid (on tomato crop - 3 days H.I.), triadimefon (on melon, cucumber and sweet pepper - 3 days H.I.), pyrazophos (melon and cucumber - 3 days H.I.), fenarimol (melon - 3 days H.I.) and sulphur (on melon, cucumber, sweet pepper and tomato crops - 0 days H.I.); insecticides of the pyrethroid group (deltamethrin, cypermethrin, alphamethrin - varying between 2 and 4 days H.I. on green beans, melon, cucumber, sweet pepper and tomato), pirimicarb (on green beans - 3 days H.I.) and the acaricide dicofol + tetradifon (on melon - 3 days H.I.)).

The answers to question no. 30 suggest that: a) growers mainly observe the harvest interval for insecticides and acaricides, while they are less heeding with fungicides; b) if an intense pest attack occurs or is likely during the harvest period or close to it, the harvest interval is often not respected.

In order to assess the amounts of pesticide residues on vegetables produced in greenhouses, surveys have been done annually in the Algarve, since 1979, and in the West, since 1982, by the Department of Toxicology of the Crop Protection Centre (Ministry of Agriculture). Some of the results of such studies are presented in Table 1 in Appendix III. They clearly show that the residues detected are mainly from dithiocarbamate and dicarboximide fungicides, with a few cases reported where growers employed a.i. on crops where they were not cleared to be used.

However, the number of cases with pesticide residues above internationally accepted Maximum Residue Levels (MRL) (defined by FAO/WHO, EC or individual western European countries) are in small number (8.2% (28/343) of the samples indicated in Table 1 of appendix III) and almost always involving dithiocarbamate fungicides (7% (24/343) of the studied samples).

To clarify this situation, several studies of dithiocarbamate fungicide residues have been done on greenhouse crops in Portugal since 1977 (Fernandes, 1979; Tainha & Cunha, 1982; Ferreira & Tainha, *in press*). From these studies it was concluded that: a) dithiocarbamate treatments done on a week or fortnight schedule could produce residues above the internationally accepted MRL, after the recommended harvest interval (7 days); b) in order to guarantee good phytosanitary control in accordance with good agricultural practices and acceptable residue levels, dithiocarbamates should be alternated with other fungicides belonging to different chemical groups; c) cleaning or washing tomatoes reduces the residue levels on the fruits very effectively.

From the toxicological point of view, problems with bisdithiocarbamates are linked with ethylenethiourea (ETU), a formulation contaminant and metabolite on plants (Vonk, 1983). In spite the fact that ETU metabolite can be lost very rapidly on plant surfaces by photolysis, the level of ETU residues can decrease slowly on the plant because of the slow breakdown of the original fungicide deposit (Smith

et al., 1988). However, propineb metabolites produced along the degradative pathway are the methyl analogues of the chemical compounds obtained by breakdown of the other bisdithiocarbamates (zineb, maneb, mancozeb, nabam), and, instead of ETU, its methyl analogue (propylenethiourea (PTU)) is obtained (Vogeler *et al.*, 1977; Vonk, 1983).

Ferreira & Tainha (*in press*) always found lower levels of dithiocarbamate residues when they applied propineb than when they applied mancozeb in a greenhouse experiment where they studied the effect of different spraying intervals on residue levels. These authors proposed that such differences could be caused by the slightly different pathway of metabolism of both fungicides.

5.3.8.3 - Assessment of available technical information

Technical information is considered insufficient by 87% of the surveyed growers in the West and 66% in the Algarve (question no. 22). However, there is a significant difference between the regions ($X^2_{[1]} = 4.16$ ($p.<0.05$)) concerning the need for technical information (Table 5.38).

In the West the number of growers willing to pay for relevant technical information is also significantly different from the Algarve ($X^2_{[1]} = 7.28$ ($p.<0.01$)), where most of the growers do not accept the idea of paying for information (Table 5.39).

Table 5.38 - Growers' assessment of technical information available

Region \ Assessment of techn. information available	I	II
WEST	4(*)	28
ALGARVE	10	19

Assessment scale:

I - Sufficient technical information
II - Insufficient technical information

(*) - Number of growers who gave this answer

Table 5.39 - Growers' assessment of the need to pay for technical information

Region \ Assessment of need to pay for information	I	II
WEST	21(*)	11
ALGARVE	9	20

Assessment scale:

I - Willing to pay for technical information
II - Not willing to pay for technical information

(*) - Number of growers who gave this answer

Growers think that technical information should be provided mainly by the Ministry of Agriculture (20 growers in the West and 17 in the Algarve). Alternatively, other possibilities included pesticide companies (2 growers in

each region), cooperatives (5 growers in the West), pesticide dealers (2 growers in the West) and even private technicians working for groups of growers (1 grower in the West).

This data shows that growers in the West are particularly worried about the lack of technical information, accept the idea that they have to pay for it and are expecting that relevant information should be provided by a wide range of information sources available in the region. By contrast, growers in the Algarve need more information but they think it should be provided almost exclusively by the Ministry of Agriculture and, because of that, they are not willing to pay for any technical information.

Cooperatives, pesticide dealers, pesticide companies and other growers or friends are the major sources of technical information and advice in the West (question no. 23) while in the Algarve pesticide dealers, other growers or friends and Ministry of Agriculture staff are the most important information sources (Fig. 5.35).

However, the range of information sources is reduced when growers try to obtain completely new information, as is the case when they face a new pest problem (question no. 25), suggesting that these are the information sources understood as a reservoir for innovative information. Again, in the West, cooperatives, pesticide dealers, pesticide companies and the Ministry of Agriculture were indicated as the information sources used by the growers,

while in the Algarve only pesticide dealers and the Ministry of Agriculture were pointed out by the majority of the growers (Fig. 5.36).

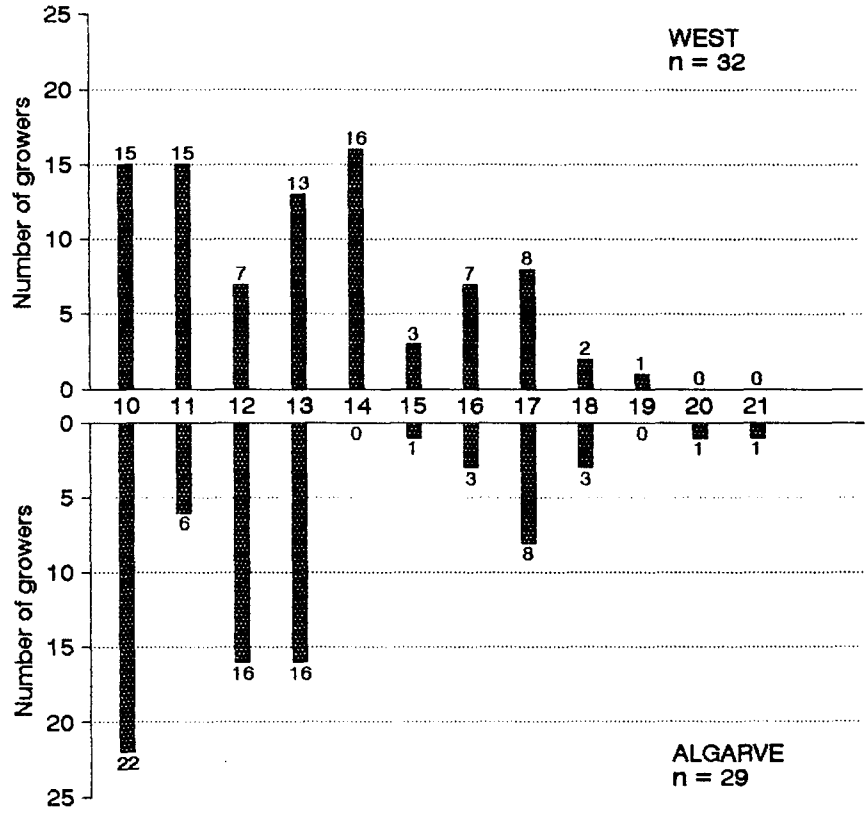


Fig. 5.35 - Current sources for technical information

10 - Pesticide dealers
11 - Pesticide companies
12 - Ministry of agriculture
13 - Other growers or friends
14 - Cooperatives
15 - Newspapers, radio, TV
16 - Technical magazines
17 - Pesticide companies literature
18 - Pesticide companies meetings
19 - Trade company who buys the yield
20 - Nursery who provides seedlings
21 - Technical course from Ministry of Agriculture

In a general way, the quality of the information obtained by the growers in both regions (question no. 24) is mainly regarded as being somewhat useful for crop protection improvements (Table 5.40).

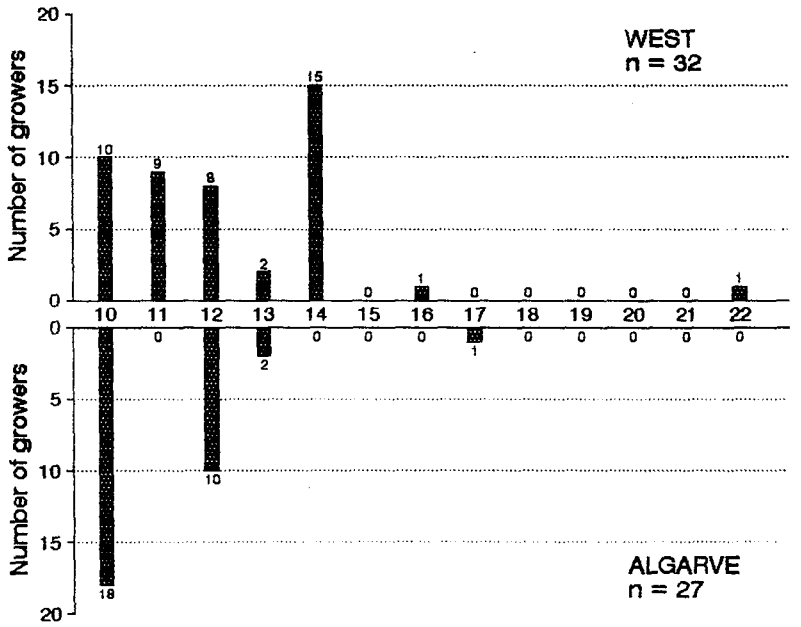


Fig. 5.36 - Sources for technical information when growers face a new pest problem

10 - Pesticide dealers
11 - Pesticide companies
12 - Ministry of agriculture
13 - Other growers or friends
14 - Cooperatives
15 - Newspapers, radio, TV
16 - Technical magazines
17 - Pesticide companies literature
18 - Pesticide companies meetings
19 - Trade company who buys the yield
20 - Nursery who provides seedlings
21 - Technical course from Ministry of Agriculture
22 - Technician working for a growers' group

Table 5.40 - Growers' assessment of usefulness of the information they obtain

\ Assess. of use- \ fulness of inf. \ obtained / Region \	I	II	III
WEST	9(*)	22	1
ALGARVE	3	21	2

(*) - Number of growers who gave this answer

$(X^2_{[2]} = 2.77$ (n.s.))

Assessment scale:

I - Information very useful
II - Information somewhat useful
III - Information not useful

In particular the information available on the label of pesticide packages (question no. 36) was never considered unnecessary or excessive and the majority of the surveyed growers considered it helpful (Table 5.41), irrespective of the region ($X^2_{[1]} = 0.87$ (n.s.)). However, a few growers claimed that they have difficulties reading all the information that must be included, by legal requirements, on the label of small bags and flasks, written in minute letters; furthermore one grower in the West had difficulties converting the recommended doses, expressed on a per hectare basis, to his particular case and area.

Table 5.41 - Growers' assessment of the information available on the label of pesticide packages

Assess. of inf. on pesticide labels / Region	I	II	III	IV
WEST	0(*)	0	22	10
ALGARVE	0	0	16	12

Assessment scale:

I - Information unnecessary
II - Information excessive
III - Information helpful
IV - Information essential

(*) - Number of growers who gave this answer

5.3.9 - Growers' attitudes to risk-taking

Growers were asked if they had any harvest insurance for greenhouse crops (question no. 40). The majority of them do

not have any insurance scheme to cover their crops (Table 5.42), but this behaviour is not independent of the region (Fisher exact test (p.=0.032)). This significant difference between the areas became more evident when growers indicated if such an insurance scheme was common amongst neighbours (question no. 40). In the Algarve almost all the growers perceived harvest insurance as being absent in their area while a significant proportion of growers in the West indicated that their neighbours had harvest insurance schemes (Fisher exact test (p.=0.0005)) (Table 5.43).

Table 5.42 - Growers' attitude to harvest insurance

Region \ Attitude to harvest insurance	I	II
WEST	23(*)	9
ALGARVE	27	2

Attitude scale:

I - Do not have harvest insurance
II - Have harvest insurance

(*) - Number of growers who gave this answer

The reason for this difference is not completely clear, since several growers in both regions complained about the conditions offered by the insurance companies to cover greenhouse crops, which farmers do not consider appropriate and which are, consequently, unattractive. However, some

credit organisations strongly recommended or even impose some insurance scheme and the differences between the regions could indirectly mean that more growers in the West are using credit facilities to establish their greenhouses, but this subject was not covered in the survey questionnaire.

Table 5.43 - Growers' perception of harvest insurance on their neighbourhood

\ Perception of harv. insurance \ on neighbourh. / Region	I	II
WEST	19(*)	13
ALGARVE	28	1

Perception scale:

I - Neighbours do not have harvest insurance schemes
II - Neighbours have harvest insurance schemes

(*) - Number of growers who gave this answer

With two exceptions in the Algarve, all the growers considered the application of pesticides as an insurance instrument to prevent sometimes serious losses rather than as an investment (question no. 41), irrespective of the region (Fisher exact test (p.=0.222)) (Table 5.44).

According to this assessment the majority of the growers only buy pesticides when necessary (question no. 35), independent of the region ($X^2_{[1]}$ = 0.38 (n.s.)) (Table 5.45). However, the group which buys pesticides in the

beginning of the season (more than 25% of the surveyed growers) adopts this behaviour mainly for fungicides, since they know they will spray regularly through the season and when they buy bigger quantities they get a discount of up to 20% of the pesticide price.

Table 5.44 - Growers' assessment of the risk strategy involving the application of pesticides on crops

\ Assessment of risk strategy \ when spraying / Region	I	II
WEST	0(*)	32
ALGARVE	2	27

Assessment scale:

I - The use of a pesticide always increases the yield
II - The use of a pesticide sometimes prevents serious losses

(*) - Number of growers who gave this answer

Table 5.45 - When growers buy the pesticides

\ When do growers buy pesticides? / Region	I	II
WEST	10(*)	22
ALGARVE	7	22

I - In the beginning of the season
II - When necessary

(*) - Number of growers who gave this answer

5.3.10 - How growers foresee future pest problems and needs in crop protection

5.3.10.1 - Importance of pests in the near future

Concerning the number of pest problems affecting the crops in the near future (question no. 32), the major proportion of growers think that their number will increase (Table 5.46), irrespective of the region ($X^2_{[2]} = 0.04$ (n.s.)), since through their past experience the growers concluded that new pest problems should always be expected.

Table 5.46 - How growers foresee the future number of pest problems

Future number of pest problems / Region	I	II	III	IV
WEST	20(*)	7	1	3
ALGARVE	19	6	0	4

I - The number of pest problems will increase in the future
II - The number of pest problems will stay the same in the future
III - The number of pest problems will decrease in the future
IV - Growers do not know

(*) - Number of growers who gave this answer

About the importance of losses caused by actual pest problems in the near future (question no. 31), the growers are much more in doubt about the evolution of actual pest

problems and about the losses they will cause. This was inferred because the majority of the growers answered this question in a cautious way selecting the middle point of the assessment scale used in the question ("STAY THE SAME") or even stating "DON'T KNOW" (Table 5.47).

Would the future importance of pest problems arise from difficulties in achieving good control (question no. 33)? Most growers do not think so but a few of them expect some difficulties in achieving good control in the future (Table 5.48).

Table 5.47 - How growers foresee the future losses caused by the actual pest problems

Future losses caused by actual pest problems / Region	I	II	III	IV
WEST	6(*)	12	6	8
ALGARVE	7	11	2	9

I - Losses caused by actual pest problems will increase in the future
II - Losses caused by actual pest problems will stay the same in the future
III - Losses caused by actual pest problems will decrease in the future
IV - Growers do not know

(*) - Number of growers who gave this answer

($X^2_{[3]}$ = 2.04 (n.s.))

Eleven growers in the West and nine growers in the Algarve, when discussing the future difficulties controlling pests, mentioned pesticide failure (Table 5.49). Nevertheless, only 7 growers in the West and 3 in the Algarve linked

Table 5.48 - How growers foresee future difficulties in achieving good control for actual pest problems

\Future difficult. to achieve good \ pest control / Region \	I	II	III
WEST	22(*)	5	5
ALGARVE	19	3	7

I - No future difficulties
II - Future difficulties
III - Do not know

(*) - Number of growers who gave this answer

($\chi^2_{[2]} = 0.91$ (n.s.))

pesticide failure with pest resistance to pesticides. The remaining growers linked pesticide failure with pesticide adulteration or changes caused by pesticide companies. This result was unexpected, since the products sold by pesticide companies need to fulfil legal requirements imposed by the Portuguese pesticides approval scheme in order to get clearance for sale, so growers are protected by law against this eventuality. In spite of the fact that such adulteration is highly unlikely, the results show that some growers are suspicious about pesticide companies.

Otherwise, the pesticide failure mentioned by the growers could be associated either with the application of pesticides in an incorrect way or with the fact that pest resistance to pesticides could be much more widespread than growers' perceptions indicate.

Table 5.49 - How growers assess pesticide failure linked with future difficulties to achieve good pest control

\ Assessment of pestic. failure / Region \	I	II
WEST	7(*)	4
ALGARVE	3	6

Assessment scale:

I - Failure caused by pest resistance to pesticides
II - Failure caused by adulteration of pesticides

(*) - Number of growers who gave this answer

($X^2_{[1]} = 1.82$ (n.s.))

5.3.10.2 - Future needs in crop protection

Most growers perceive the following needs for the future (question no. 34) in order to improve pest control practices (Fig. 5.37): a) more information about pesticides and application methods; b) more information about pests and the losses they cause; c) more effective pesticides. In other words, growers want to improve the efficacy of pest management practices, and for that they need more information as a basic device.

The availability of resistant cultivars and cheaper pesticides, an efficient advice service as well as better application equipment are the improvements which come lower in importance (Fig. 5.37).

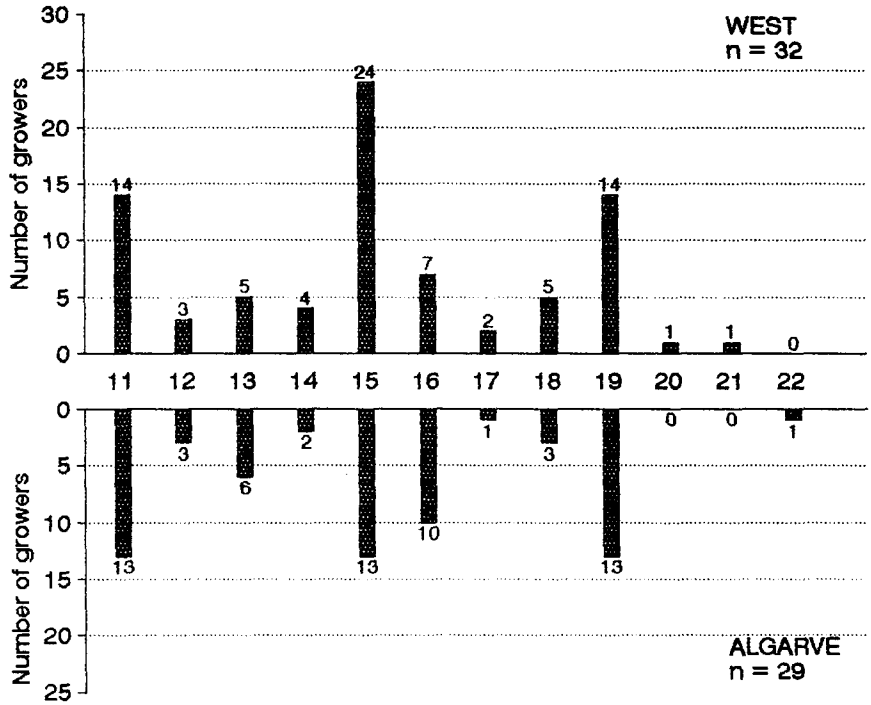


Fig. 5.37 - Improvements necessary for the future in crop protection

11 - More effective pesticides
12 - Safer pesticides
13 - Cheaper pesticides
14 - Better spraying equipment
15 - More information on pesticides and application methods
16 - Resistant cultivars
17 - Non-chemical control methods
18 - Effective advisory services
19 - More information on pests and losses
20 - Information about manure amounts needed in the soil
21 - Analysis of pesticide residues available to growers
22 - No change; happy with the actual situation

5.3.10.3 - Other comments linked with future needs in crop protection

To assess if the survey questionnaire missed any important problem concerning pests and crop protection, which could be an important one in the future, growers were asked if they would like to add any other point to the discussion (question no. 44).

The majority of them (22 growers in the West and 24 in the Algarve) were reasonably happy with the survey questionnaire (or with the end of it), since no other comments or points were produced (Fig. 5.38). However, 5 growers in the West and 2 in the Algarve mentioned, again, the need for technical assistance and diffusion of information, coming to the main point that one of the key limiting factors of this agricultural system in Portugal is a "technical information gap".

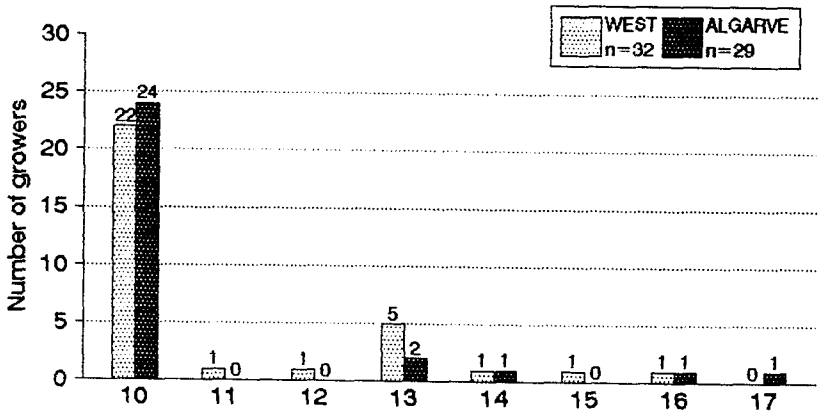


Fig. 5.38 - Other problems perceived as being important and not discussed deeply enough in the questionnaire

10 - No other problem
11 - Deeper discussion of the pest problems, problem by problem
12 - Pollution of irrigation water by other farmers (animal husbandry)
13 - Technical assistance and diffusion of information
14 - Problems with greenhouse insurance schemes
15 - Marketing problems
16 - Greenhouse structure and cultural practices
17 - Safety of the applicator of pesticides

All the other items mentioned at this point were only indicated by one grower each (Fig.5.38) and include subjects varying from research on improving the structure of greenhouses and water pollution faced by some growers

caused by animal husbandry in the region (there are no slurry regulations or controls in practical terms in Portugal), to safety schemes for the applicator of pesticides and to marketing problems faced by the growers.

6 - THE USE OF AN EXPERT SYSTEM TO DESCRIBE AND IMPROVE DECISION-MAKING

6.1 - INTRODUCTION

The delivery of information to decision-makers at the production level has been considered a major problem faced by researchers in agriculture (Getz & Gutierrez, 1982). Norton & Mumford (1982) considered that, in many cases, improvements on crop protection decision-making can be achieved by reducing the information gaps that exist at the farm level. Problems with technology transference still continue to be identified as the major constraint limiting IPM progress (Wearing, 1988). Recently, Coulson *et al.* (1989) reinforce these opinions, claiming that, in order to succeed, researchers developing IPM strategies should concentrate both on increasing scientific knowledge and, more important, on ways to transfer the available knowledge to decision makers currently facing such problems.

It is widely believed that the use of computers in agriculture will be increasingly important in the future, providing information and assisting managerial decisions, including pest control decision-making (Welch, 1984; Holt, 1985; Stone *et al.*, 1986).

Several types of computer systems were developed in order to improve this task. Some of those systems, besides providing information, can even simulate the decision-

-making process employed by experts on specific domains of knowledge (Coulson & Saunders, 1987).

Such systems, called "Expert Systems", derived from the development of artificial intelligence techniques in computer science, and began being used on practical applications, including agriculture and pest management, from the mid 1980's. As indicated in Chapter 4.3 these systems can be used to improve decision-making in agriculture.

In this Chapter the potential of using an "Expert System" as a tool to help describe decision problems faced by growers concerning greenhouse pests is illustrated, as well as its capabilities to provide decision-makers with the relevant technical information they need.

Expert system computer programs consist of several independent components comprising a knowledge base, an inference engine and a user interface (Frenzel, 1987). The knowledge base contains all the facts, rules and structures employed to solve problems in a specific domain of expertise; the inference engine uses the information in the knowledge base and performs the logical operations to reach a solution for the problems entered by the users; and, the user interface allows an easy communication between the user of the system and the system itself.

Expert systems are also sometimes called Knowledge-based systems (Coulson & Saunders, 1987; Rauscher, 1987), because of the existence of a domain-specific knowledge base.

However, since a knowledge-based system does not necessarily use heuristics for problem solving and an expert system "*...embodies all of the facts, information, knowledge, rules of thumb and other elements of heuristic expertise in a specific domain...*" (Frenzel, 1987), expert systems are a particular sub-class of knowledge-based systems (Sell, 1985).

Commercial expert system shells provide an inference engine and a user interface, therefore, only the knowledge base needs to be developed. However, it must be developed according to the specifications of the shell and, in some cases, this could represent a major limitation for the structure of the knowledge base (Denne, 1988). Otherwise, the use of expert system shells allows a fast and easy approach to the technique without major programming (Frenzel, 1987).

There are four potential uses of knowledge-based systems in general, and expert systems in particular, in pest management: a) *Practical problem solving*, like diagnosis of current pests and recommendation of control options; b) *Information processing and provision*, related with the utilisation of historical information on the decision process or the assessment of potential situations; c) *Problem structuring*, in order to highlight information gaps and management needs which could improve pest control; d) *Training*, either for extension agents or students (Mumford & Norton, 1989).

For greenhouses, some expert systems or knowledge-based systems have been developed, ranging from environmental control inside greenhouses (Kozai, 1985), to diagnosis of diseases on vegetable crops like tomato (Kozai & Hoshi, 1985; Blancard *et al.*, 1985).

6.2 - CASE STUDIES: TOMATO GREY MOULD AND CATERPILLARS

The development of an expert system for a particular domain of knowledge involves an accurate definition of the problem to be solved, the organisation of facts, rules and decision steps to solve the problem and, finally, the formalisation and representation of the knowledge base in a computer programme (Holt *et al.*, *in press*; Jones *et al.*, *in press*). Later, such a system must be validated and maintained as accurately as possible through frequent up-dating (Frenzel, 1987; Parsaye & Chignell, 1988).

The initial phase of such development comprises the programming of a demonstration prototype in order to show the viability of the approach, using a subset of the domain knowledge, before a research prototype is fully implemented (Frenzel, 1987). A demonstration prototype of an expert system can be use to test and prove its potential to help decision makers solve problems. Furthermore, a prototype helps to describe the actual decision-making process and the structure of the decision problem (Sell, 1985).

A demonstration prototype developed in this study

(illustrated in Appendix IV) deals with two common pest problems affecting vegetables in Portuguese greenhouses; its task is to describe the decision process adopted for their control, while assessing its potential as an information source for growers and their advisors in the future, since this was identified as a major need in the near future (Chapter 5.3.10.2).

The prototype structure is based on two choice levels: the crop and the pest problem. For each particular pest problem a decision tree is adopted, as illustrated in Figs. 6.1 and 6.2.

After selecting the crop, the user is presented with a list of the major pest problems identified through the survey described in the previous chapter, and for each pest problem the system runs through the decision tree, asking questions, providing information about decision factors and indicating strategic and tactical control options. The demonstration prototype was developed only for the tomato crop, since this is the most important greenhouse vegetable in Portugal, as shown in Chapters 3 and 5. Grey mould and caterpillars were selected as the predominant pest problems on this crop because they occur widely in both regions covered by this study (Chapter 5.3.6.2) and represent the decision-making process faced by growers to control common diseases and arthropod pests in greenhouse crops. These decisions involve questions on what strategic and tactical control methods should be employed; when to spray; how regularly; which pesticides to use; and, which application

methods?

As the occurrence of decision points and the adoption of control options are dependent on the biology of the pests being considered and relations with their host plants, detailed biological information relevant to the decision problems was included in the knowledge base.

The knowledge of the subject was obtained from the literature, from intensive discussions with growers and technical staff either during the exploratory survey or the formal survey performed in Portugal (Chapter 5.2), and from the author's own expertise as a result of his past training.

If the development of an operational system is to be considered in the near future the knowledge base needs further discussion with other domain experts. A subset dealing with diagnosis of pest problems may need to be included in the expert system. However, at this stage, it is assumed that the users are able to recognise the major pest problems affecting the main crops in greenhouses, based on the information presented in Chapter 5.

The computing and programming tasks necessary to formalise and represent the knowledge base were performed using a commercial shell. The software package used has been **KnowledgePro** (KNOWLEDGE GARDEN Inc.) (Thompson & Thompson, 1988), a rule-based expert system shell, with good capabilities to display information screens. This was considered important in the present case study since

providing relevant technical information is a major objective of the prototype system.

6.2.1 - Tomato grey mould

Grey mould attacks on greenhouse tomatoes are difficult to control because of the way the infections become established (through conidia either on flowers or fruits and from saprophytic mycelium on leaves, stems or fruits) and because the inoculum of the disease can reach very high levels in greenhouses under favourable environmental conditions (Smith, 1970; Blakeman, 1980; Verhoeff, 1980). In such circumstances chemical control of grey mould can be very difficult to achieve (Locke & Fletcher, 1988).

The development of the disease is weather dependent. Conidia only germinate with relative humidity (R.H.) between 93% and 100%, and, although the optimum temperature for vegetative growth of the fungi is above 20° C, the optimum temperature for appresoria formation is between 15--20° C (Blakeman, 1980). Under practical conditions, grey mould is a disease which prevails during cool and humid weather with temperatures ranging from 7° C to 16° C and rainfall or very wet periods (Maude, 1980). However, the optimal temperature for disease development ranges from 17--18° C to 23° C (Blancard, 1986; Agrios, 1988). According to some authors, temperatures above 22-25° C seem to depress the incidence of the disease in other crops, like strawberries (Jarvis, 1980b).

From the information presented above it is clear that under cool conditions (say temperatures below 25° C), the key environmental factor for grey mould development is the atmospheric moisture content. The occurrence of a period with R.H. at or above 90% during 18 hr, at 20° C, was recently proposed as an "*infection period*" for grey mould on tomato (Polley, 1986). However, Smith (1970) obtained "ghost-spotting" symptoms on tomato fruits when these were incubated during 8-10 hr at 19-20° C and 93% R.H. but she adopted an experimental incubation period of 17-19 hr with R.H. above 93% for her inoculation trials.

The inocula sources are usually residues from previous crops or neighbouring crops (Blancard, 1986). As *Botrytis cinerea* has over 200 hosts (Jarvis, 1980a), the disease is very common and widely distributed in the environment, with no lack of inocula sources. Inside greenhouses, the initial infections are scattered through crops (Honda *et al.*, 1977) and these primary infections in flowers and fruits are responsible for the build-up of conidia amounts in the structure and for saprophytic-based mycelium infections.

B. cinerea is a weak parasite affecting mainly senescent and wounded tissues; conidia germination is stimulated by nutrients present in leachates from plants (Blakeman, 1980, Verhoeff, 1980). On tomato these conditions are present over a long period, either on senescent flowers and senescent vegetative organs or on any wounds resulting from training, deleafing, other plant management operations, pest attacks or any other injurious events.

Nutrient leakage is less on leaves than on flowers and fruits and inhibitory phenolic substances are present (Verhoeff, 1980), so conidia germination mainly occurs on flowers and small, matted or semi-matted fruits (Smith, 1970). Many infected flowers drop onto leaves or fruits below, acting as a source for secondary infections, which can affect almost every organ of the plant. Otherwise, flower petals can remain attached to the fruits, providing ideal conditions for secondary infections. This can be increased by the use of fruit-setting growth substances on flower trusses (Newhook & Davison, 1956). Infections can also remain in a latent form in wounds and flower calyces and develop later (Verhoeff, 1980).

Apart from availability of inoculum and favourable environmental conditions, grey mould incidence is also dependent on crop susceptibility, which can be affected by cultural factors. However, as Smith (1970) demonstrated, major modifications on cultural factors have adverse effects on quantitative and qualitative aspects of the yield. Those factors affecting crop susceptibility are linked with the plant itself and with external conditions acting on the plants.

As stated above, the existence of senescent tissues is a major factor on disease development. Greenhouse tomatoes have "indeterminate" growth, the main stem regularly producing new leaves, flowers and fruits. At the same time lower leaves and flowers regularly become senescent as fruit setting progresses along the stem, creating

susceptible substrates for infections after the first trusses reach fruit-setting stage.

Another factor is linked with the phenological stage of the plant at transplanting: tomato seedlings transplanted at the second true leaf stage are more susceptible than seedlings transplanted later, at first truss budding or flowering, but yield suffers a significant reduction in the latter situation (Smith, 1970). In addition, crop density is an important factor, since an adequate spacing between plants can greatly improve ventilation in the plant canopy (Maude, 1980).

Soil conditions also affect crop susceptibility, such as fertiliser levels, soil pH values and irrigation regimes.

The effects of nitrogen levels in the soil have been correlated negatively with grey mould number of infections (Verhoeff, 1965, 1968). However, Smith (1970) did not find any effect of soil nitrogen levels on the incidence of grey mould stem infections; instead, she found that high levels of soil phosphorus associated with low levels of potassium increased the incidence of grey mould stem infections. Stall *et al.* (1965) reported a similar effect associated with the use of high levels of soil phosphorus and low levels of calcium. Verhoeff (1980) suggested that the accumulation of carbohydrates on tomato plants, as a result of high levels (nitrogen or phosphorus) or low levels (potassium or calcium) of major nutrients, will increase the plant susceptibility to grey mould attacks as a result.

Soil pH, while restraining the availability of many nutrients in the soil, has been linked with grey mould infections on tomato leaves and fruits: pH values below 5 are more favourable to the disease than values around 6-6.5 (Stall, 1963). Nevertheless, Stall *et al.* (1965) suggested that soil pH may only have a secondary effect on grey mould infections.

Irrigation regimes which maintained soil water content close to field capacity were associated with higher rates of grey mould stem infection than irrigation schemes which maintained low soil moistures in the rooting zone (Smith, 1970).

External aerial conditions affecting crop susceptibility are: pollutants (tomato flowers are known to be particularly sensitive to ethylene before anthesis (Atherton & Harris, 1986)); the occurrence of low temperature periods or frosts; and even spraying of bisdithiocarbamate fungicides on the plants (Lockhart & Forsyth, 1964; Smith, 1970; Jarvis, 1980b).

In accordance with the biological characteristics of grey mould and the susceptible conditions of the crop, briefly discussed above, preventive spraying schemes have been recommended as the most effective control strategy for grey mould in unheated greenhouses. Treatments should begin when the first flowers become senescent and must be repeated regularly (eg every 14 days) to guarantee a permanent coverage of the plant (Smith *et al.*, 1975). These authors

also showed the importance of commencing the spray scheme before disease infection occurs, while many growers reportedly began preventive spraying only after disease symptoms were visible (Smith, 1970).

Attempts to forecast the initial disease infection, in order to rationalise the timing of the initial spray, were made by Polley (1986). The author compared the standard procedure (routine sprays every two-weeks commencing at fruit-setting of the first truss, flowering of the second truss) with an action threshold of 5% of infected flowers after flowering of the second truss and with the occurrence of an "infection period" (18 hr. with R.H. above 90%) after the flowering of the second truss. He concluded that the action threshold based on the percentage of infected flowers was not useful as a spraying time indicator, while he obtained good results with the utilisation of the "infection period" concept, when compared with the standard procedure.

Apart from chemical control, other strategies for grey mould control in unheated greenhouses are only linked with cultural methods. Biological control is far from being available to commercial growers in spite of successful experimental results with antagonistic fungi, like *Trichoderma harzianum* Rifai (Blancard, 1986) or *Trichoderma viride* Pers. ex. S.F.Gay (Lemaire *et al.*, 1988). There are no tomato cultivars resistant to grey mould (Stevens & Rick, 1986). Differences in disease infection levels found amongst different cultivars (Smith,

1970) seem to be related to differences in the microclimatic conditions inside the plant canopy (Watterson, 1986).

Cultural methods are performed to: a) reduce the amount of disease inoculum; b) reduce plant susceptibility to the pathogen; c) eliminate or reduce environmental conditions favourable to the disease inside greenhouses.

In unheated greenhouses the usual cultural measures employed to fulfil those objectives are regular deleafing of senescent leaves, removal of infected tissues (ex: leaves, dropped fruits) from the greenhouse and ventilation of the structure.

Deleafing normally starts before the first picking, when fruits begin ripening (Smith, 1970) or alternatively when the fourth truss is setting (Nisen *et al.*, 1988). Under commercial conditions deleafing intensity varies considerably and usually more leaves are removed during earlier phases of the crop (Smith, 1970), as deleafing is also regarded as a way to increase earliness of production (Nisen *et al.*, 1988).

In general all the leaves up to the first or second truss are removed during first deleafing and the process is repeated regularly through the season, keeping at least four trusses with leaves (Smith, 1970; Nisen *et al.*, 1988).

When deleafing, many Portuguese growers cut the petiole several cm's apart from the stem, leaving sometimes

quite long stumps (as indicated at Chapter 5.3.4.8). However, breaking off the petioles close to the stem has been regarded as the best deleafing method (Verhoeff, 1968).

In heated and tight greenhouses the automatic control of temperature and humidity provides extra possibilities of control since the environmental conditions favourable for grey mould development can be avoided (Winspear *et al.*, 1970).

Another attempt to change environmental conditions favourable for the disease is represented by Japanese works employing ultraviolet-absorbing vinyl films on greenhouse structures (Honda *et al.*, 1977). Such films have a lower limit of transmission for solar radiation at 390nm, excluding almost all the ultraviolet (UV) radiation. Since "field" strains of grey mould need to be exposed to UV light to sporulate (Epton & Richmond, 1980), under these conditions the potential for increase of disease inoculum, after initial infestations, is greatly reduced which was demonstrated by the Japanese researchers.

The existence of grey mould strains which can sporulate in the dark (Epton & Richmond, 1980) carry the potential problem of "selection pressure" imposed by the plastic film if the process was widely adopted. However, Honda *et al.* (1977) claimed that such risk is almost only theoretical because they found that grey mould strains insensitive to UV light are almost non-existent under natural conditions.

The decision tree used to discuss grey mould control on tomatoes, under Portuguese greenhouse conditions is represented on Fig. 6.1.

The first node is intended to recommend immediate action if disease symptoms are already present in the crop, to prevent the build-up of the disease, which could jeopardise the efficacy of chemical control. In the particular situation where preventive spraying did not prevent the development of the disease and subsequent symptoms, a reassessment of control methods tactics is recommended (Fig. 6.1).

The decision to begin preventive sprays is dependent on the existence of susceptible tissues on the tomato plant (the standard method as defined above is adopted here, indicating the flowering of the first truss as the decision-factor because some growers in the Algarve claimed that sometimes the first truss is lost (Table 5.16)) and on the existence of favourable weather conditions for the disease (temperature is assessed on the scale "cool" and "hot", which roughly means below and above 22-25° C; humidity is assessed on the scale "rainy", "cloudy" and "clear", meaning very high humidity (100% R.H. or close to it), high humidity (around 90-95% R.H.) and medium-low humidity (below 75-80% R.H.)).

When the crop reaches a susceptible phenological stage:

i) under conditions of very high humidity and low temperature, preventive sprays are immediately

recommended;

ii) if the weather is unfavourable to grey mould spraying should be delayed a few days, depending on the way environmental conditions evolve;

iii) under cloudy weather, irrespectively of temperature, the decision for control must depend on the forecasting for the next day, next two days ahead: if the weather improves but the crop is considered to be particularly susceptible to grey mould attack preventive sprays should be made; otherwise spraying should be delayed a few days, depending on risk assessment based on regular monitoring of the crop and weather conditions the days ahead (Fig. 6.1).

Finally, tactics to select and apply fungicides are discussed.

The fungicides cleared by the Portuguese pesticides approval scheme to be used on tomato against grey mould are: benomyl, dichlofluanid, iprodione, procymidone and vinclozolin (D.G.P.P.A., 1980; 1984 and appendices).

Initial treatments should be made with fungicides which are particularly effective against conidia germination. The phenylsulfamide dichlofluanid is very active against germination of grey mould conidia and is the most effective fungicide to control "ghost-spotting" on fruits (Smith *et al.*, 1975; Morgan, 1979b).

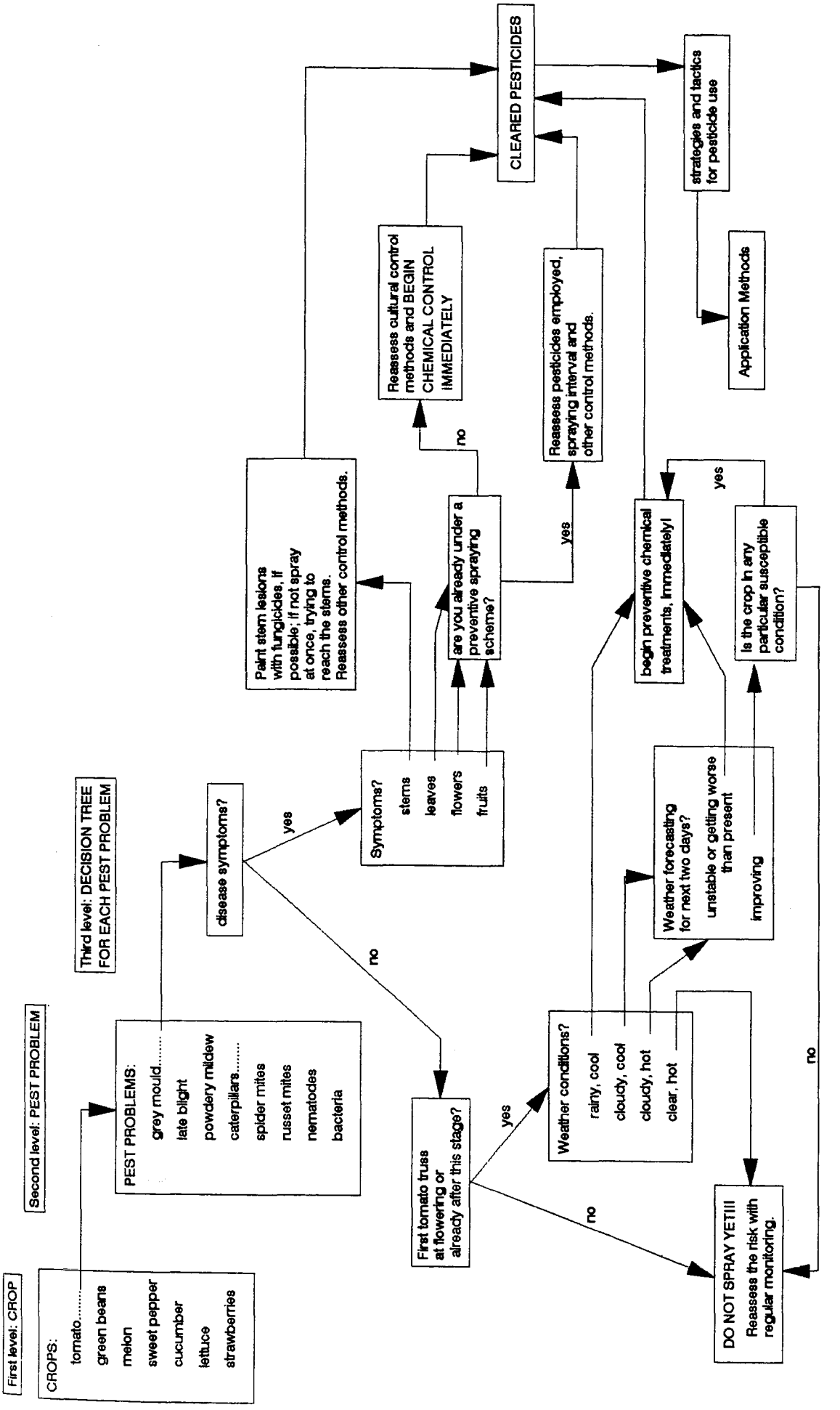


Fig. 6.1 - Decision-tree for the control of tomato grey mould in greenhouses

Later in the season, or after infection development, treatments should be done with fungicides more active against mycelium growth, to prevent development of latent infections and saprophytic-based mycelium infections. Dicarboximides (iprodione, procymidone, vinclozolin) are very efficient to control saprophytic-based mycelium infections on the leaves and stems (Morgan, 1979b). The cleared benzimidazole fungicide, benomyl, when sprayed on the plants is mainly a protective fungicide; if applied to the soil (where it is very static, absorbed on organic matter and clay particles) it is translocated mainly to the leaves, the movement being regulated by the transpiration rate (Hassall, 1982; Davidse & Waard, 1984).

Deleafing and breaking off side-shoots should be performed just before spraying in order to protect stem wounds, since it takes the plant about a week to develop a cambial layer of cells to seal the wound (Verhoeff, 1967).

The spraying interval recommended for preventive schemes, as indicated above, is usually two weeks based on persistence of and "weathering" effects on pesticide residues and the need to protect new growth (Smith *et al.*, 1975; Vanachter *et al.*, 1979; Polley, 1986). Nevertheless, in practical conditions, under severe grey mould attacks, spraying may be done once or twice a week even with fungicide concentrations above the recommended rates (Katan, 1982), a solution also adopted by many Portuguese growers (Chapter 5.3.6.4).

During cool and humid weather tomato plants have low growth and transpiration rates; as a consequence new tissues are developed slowly and plants can only absorb limited amounts of systemic pesticides, which limit the application of benomyl as a soil drench. Under the assumption that dicarboximides tend to be widely used during such weather conditions, and bearing in mind the limited nonbiological hydrolysis of iprodione and vinclozolin under natural circumstances (Melkebeke *et al.*, 1986) and the reduction of dicarboximide residues on tomato to negligible levels only after three weeks (Vanachter *et al.*, 1979) if not washed out by other sprays, spraying once a week during risky periods should provide enough protection to the crop and still allows growers to harvest fruits twice a week (only for vinclozolin, other dicarboximides have a harvest interval of 7 days). Otherwise, very frequent sprays cause high residue levels on the fruits and high volume treatments introduce high amounts of water in the greenhouse during a time when the moisture content is already very favourable to the disease.

To prevent expansion of stem lesions these should be painted with benomyl, iprodione or vinclozolin. Their effect can be increased by the addition of a mineral oil (Channon & Thompson, 1977) and the recommended concentration of the paste is about 300 g a.i./l (Ledieu *et al*, 1989). However, this technique is very time consuming and alternatively soil drenches of benomyl can be applied monthly or sprays with the above mentioned fungicides

should be performed every fortnight (Channon & Thompson, 1977; Morgan, 1979b). In the latter case a good coverage of the stem should be guaranteed.

Repeated applications of benomyl can select resistant strains very fast and those can stay for long periods in the environment even in the absence of selection pressure from pesticides of the benzimidazole group (Kato *et al.*, 1983; Locke & Fletcher, 1988). Repeated applications of dicarboximides impose the necessary selection pressure for the emergence of grey mould strains resistant to these compounds too (Katan, 1982; Locke & Fletcher, 1988).

To avoid this problem the adoption of spraying programmes involving alternating or tank-mixing pesticides, belonging to different chemical groups and having different modes of action, have been recommended and practised. With such a few fungicide groups to control grey mould on tomato the actual choice is almost restricted to alternate or mix dichlofluanid with dicarboximides. At the moment there are some doubts about the real impact of this strategy to avoid or delay resistance appearance, with some authors indicating apparent failures (on strawberry crops (Hunter *et al.*, 1987)) and others suggesting apparent advantages (Locke & Fletcher, 1988).

As resistant strains to a particular pesticide are sometimes able to develop even in the presence of concentrations some degrees of magnitude higher than the recommended ones, it is reasonable not to increase the

recommended concentration as a general procedure, especially if a resistant situation is suspected.

High volume (H.V.) sprays are generally regarded as the most effective application method to control grey mould and are the most commonly used spraying method (Fletcher, 1984). But the high amounts of labour, time and water necessary for the task justify the utilisation of other application methods easier to apply than H.V. sprays. The adoption of rotary atomisers in greenhouses has been done for crops with open canopies, but on crops with dense canopies their use result in a very uneven spray deposit (Powell & Lindquist, 1986). Thermal fogging has been employed to control grey mould on greenhouse tomatoes as an alternative to H.V. sprays with good results (Morgan & Spencer, 1978; Morgan, 1979a; Robinson & Wilson, 1979). However, the frequency of fogging needs to be greater than the frequency of H.V. spraying (once or twice a week) to achieve a comparable level of disease control (Morgan & Spencer, 1978), and growers must be made aware of limitations associated with this technique, discussed in Chapter 5.3.6.5.

6.2.2 - Tomato caterpillars

Several species of caterpillars have been found attacking tomatoes in Portuguese greenhouses (Table 3.8). According to their feeding behaviour on tomato it is appropriate to divide them into three broad groups: a) cutworms; b) leaf

caterpillars; and, c) fruit caterpillars, to discuss a control strategy for each group.

Cutworms are represented by the species *Agrotis segetum* (Denis & Schiffermüller).

Agrotis segetum begins to fly in Iberia in February, with the peak of the first generation at May-June and a second generation from July to September; in some places a third generation occurs from September to December (Bustillo *et al.*, 1984). Eggs are laid in small irregular masses, up to 1,000 per female, on stems of crop plants or weeds, close to the soil or even on the ground among plant residues. They hatch in 10-20 days and the two first instars feed on the aerial part of the plants (Carter, 1984). In this phase larvae are difficult to detect (Poitout & Bues, 1982). Later they adopt their characteristic behaviour, feeding at or below ground level, cutting off seedlings and boring into roots or tubers. However, larvae need dry soil in which to hide since wet soil is not suitable for larvae hiding (Esbjerg, 1988). It pupates in the soil. Adults fly at night. Overwintering is in the soil as larvae (Carter, 1984).

Leaf caterpillars include *Autographa gamma* (L.), *Chrysodeixis chalcites* (Esper), *Mamestra brassicae* (L.), *Spodoptera exigua* (Hübner) and *Spodoptera littoralis* (Boisduval).

Autographa gamma - In Iberia this species has three generations a year with peaks in May-June, August and

September. However, under favourable environments, generations can continuously breed (Bustillo *et al.*, 1984). Furthermore, adults can immigrate from Northern Africa (Carter, 1984). Eggs are laid singly or in small batches, both on the upper side or on the underside of the leaves with very few on the stems, up to 500 per female. Very rarely eggs occur within 5 cm of the ground and they hatch in 6-12 days (Hussey *et al.*, 1969; Burges & Jarrett, 1976; Carter, 1984). The caterpillars are "semi-loopers", which feed on the foliage and are difficult to find, but the frass granules they produce, which accumulate below the feeding place, are easy to find (Hussey *et al.*, 1969). Pupation is among spinned leaves or in crevices on the greenhouse structure (Jarrett, 1985a). The adults fly by day and night (Carter, 1984).

Chrysodeixis chalcites - This species has a biology and life cycle very similar to the previous species *Autographa gamma* (Rivnay, 1962).

Mamestra brassicae - In Iberia this species has two generations a year, the first generation in April-June (when it reaches the peak) and the second generation in late August which can last until October (Bustillo *et al.*, 1984). Eggs are laid in dispersed groups of 20-100, on the underside of the leaves and on the greenhouse structure, up to the maximum of 500 per female (Jarrett, 1985a). Egg laying probably occurs in the early hours of darkness (Burges & Jarrett, 1976). Eggs hatch in 8 days (Hill, 1987). Larvae feed gregariously on the underside of the

leaves during the first instars and later disperse (Hill, 1987). When they are disturbed they tend to curl (Carter, 1984). Pupation is in the soil (Carter, 1984). Inside greenhouses moths accumulate along the walls, particularly close to the corners, and either hide themselves in crevices of the structure or distribute themselves against surfaces (Burges & Jarrett, 1976).

Spodoptera exigua - In Iberia, in areas with favourable weather, this species can produce successive generations throughout the year; furthermore, populations can be increased by immigrant moths coming from the south from April to September (Bustillo *et al.*, 1984). Eggs are laid on the underside of the leaves in batches up to 100 in several layers and covered with scales (Carter, 1984), within 10 cm of the soil (Smits *et al.*, 1986). Eggs hatch in 2-4 days (Hill, 1987). Larvae feed mainly at night, on the underside of the leaves and are very gregarious; on average they go through six instars in less than 13 days (Carter, 1984; Hill, 1987). Pupation is in the soil, just below the surface (Carter, 1984).

Spodoptera littoralis - In southern parts of Iberia this species produces continuous generations throughout the year and during spring and early summer moths migrate to the remaining areas where they produce one generation (Bustillo *et al.*, 1984). Eggs are laid on the underside of the leaves in clusters of 20-500 which are covered with pale-brown scales (Carter, 1984). They hatch in 2-6 days (Hill, 1987). Each female lays between three and seven clusters (Hafez,

1978). Larvae go through six instars, which can take from 12 to 33 days depending on temperature, and they are very gregarious during early instars; they eat at night (Hafez, 1978; Carter, 1984). Pupation occurs in the soil, close to the surface (Carter, 1984). The adult flies at night, particularly in the early morning before sunrise (Hafez, 1978).

Fruit caterpillars include *Helicoverpa armigera* (Hübner). (*Spodoptera littoralis* can sometimes bore into and feed inside tomato fruits located near or touching the soil, but larvae of this species are mainly leaf-eaters (Hafez, 1978). The same behaviour was indicated for *Spodoptera exigua* (Balachowsky, 1972); however, in greenhouse tomatoes the larvae mainly feed on lower leaves (Smits *et al.*, 1987a)).

Helicoverpa armigera - In Iberia this species can have between two and four generations a year, from March to October, according to the local climate, but this pattern can be masked by adult migrations from other areas (Bustillo *et al.*, 1984). In the south of Portugal this species has three peaks in June-July, August and September, with an interval of five weeks between each of them, the second one being the most important (Meierrose & Araujo, 1986). Eggs are laid singly, up to 1,000 per female, both on upper and lower sides of the leaves and close to flower trusses (Carter, 1984). Under tomato field conditions Meierrose & Araujo (1986) found that more than one egg per complete leaf and more than five per plant are very rare

events, with three quarters of them located on the underside of the leaves. Eggs hatch in 2-10 days (Carter, 1984). Larvae can feed during the first instars on leaves but soon they bore into fruits and each one can destroy several fruits on the same truss during their development (Poitout & Bues, 1982). Pupation occurs in the soil; at the end of the season pupae diapause to overwinter (Tunstall, 1978). Adults fly mainly at night (Carter, 1984).

Usually caterpillars are a problem in greenhouses as a result of moths attraction to food sources and the existence of suitable places for oviposition. Eventually larvae pupate inside greenhouses and can even overwinter there but growers' comments (Tables 5.16 & 5.17) support the idea that caterpillar infestations result mainly from moths coming from outside the structure, during a period (summer-autumn) when vegetation inside greenhouses is much more attractive to moths than vegetation outside. Bues *et al.* (1987) reported a similar pattern in the south of France, where larvae of *H. armigera* cause losses on greenhouse tomatoes after mid-August, September (third generation), which coincide with harvesting on field tomato crops.

Adult flight could be monitored either with light-traps or pheromone traps for all the species involved (discussed above). However, such tools are not used by growers. Pheromones are not available on the Portuguese market at the moment and light traps could be responsible for the

attraction of further moths from outside the greenhouse, as Foster (1986b) found in Scotland. Furthermore, the experimental results currently available suggest that the effectiveness of pheromone traps for monitoring purposes inside greenhouses is very low (van den Bos, 1983). Without information on flight periods growers rely on larvae or egg detection through regular and careful monitoring of the crops.

The decision tree used to discuss caterpillar control on tomatoes in Portugal is represented in Fig. 6.2.

The first node is intended to recommend immediate action if larvae are present on the crop (Fig. 6.2), since larvae become less susceptible to pesticides as they grow and some species (like *H. armigera*) hide in places very difficult to reach with pesticides.

If larvae are not present on the crop growers should check for egg presence on the underside of the leaves, checking leaves located at different heights along the stem, either in central areas of the structure or along the walls, during their regular crop monitoring activities (see 5.3.8.1). If eggs are detected, growers must be particularly attentive during the next week's monitoring in order to detect young larvae as early as possible and initiate control actions; if eggs are not detected spraying should be delayed until eggs or larvae are perceived on the crop through regular monitoring (Fig. 6.2).

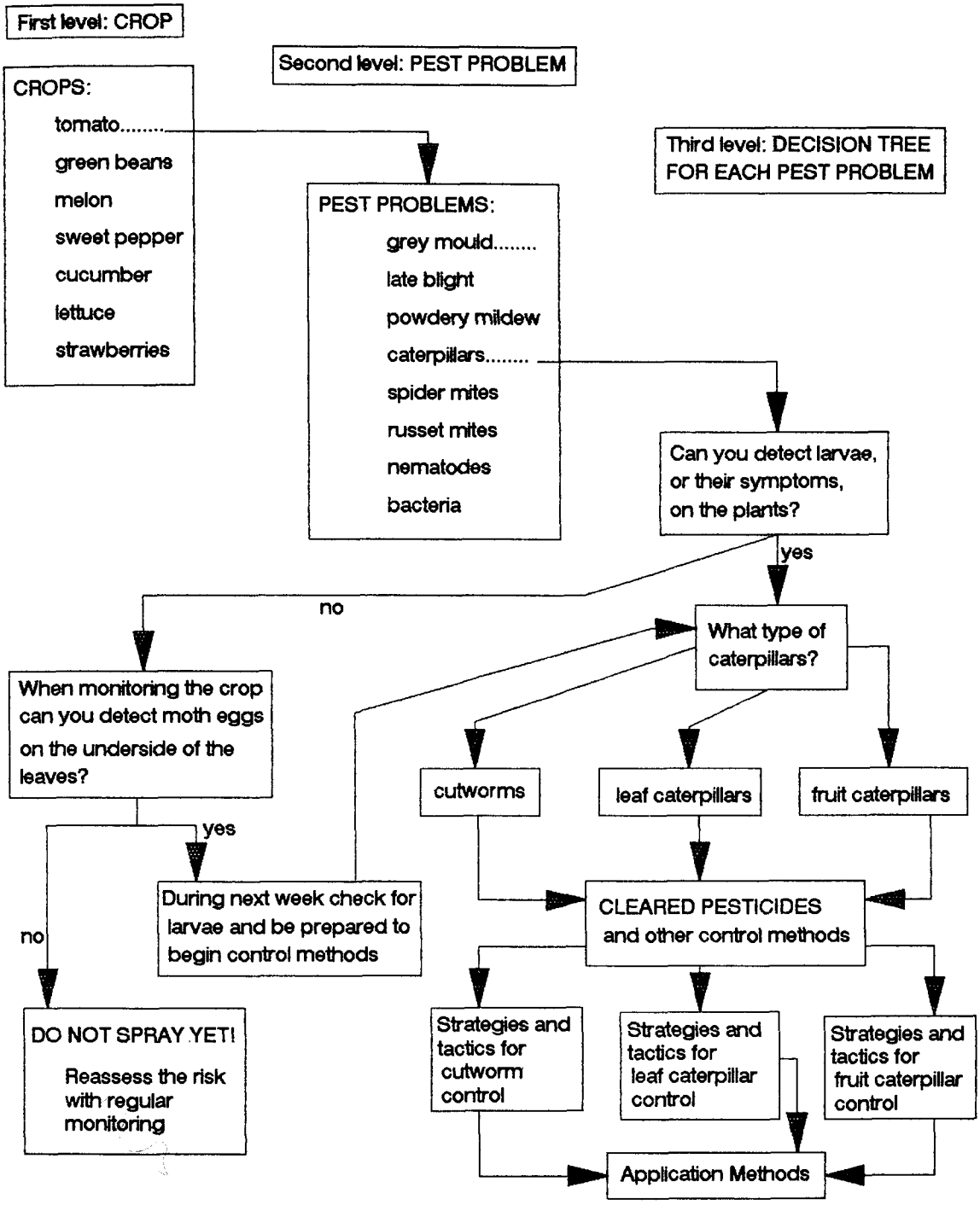


Fig. 6.2 - Decision-tree for the control of tomato caterpillars in greenhouses

The strategy of opportunistic spray adopted by many growers against caterpillars, by adding an insecticide to routine fungicide sprays, is a potentially risky strategy in terms of selection pressure on caterpillars but also on other pests like whiteflies. Also in economic terms the efficacy of such a strategy seems doubtful (3 growers in the West spraying only after larvae detection reported crop losses of 1% on average while 1 grower in the Algarve spraying routinely indicated 0% of losses (Table 5.36); the average pest incidence reported by the growers in the West was 3% (Table 5.31)).

Once an infestation is detected growers have a pesticide choice problem. The insecticides cleared by the Portuguese pesticides approval scheme for use on tomato against leaf and fruit caterpillars vary from OP's (like acephate, azinphos-ethyl, azinphos-methyl, chlorpyrifos, diazinon, methamidophos, mevinphos, parathion, trichlorfon amongst others (see list included in Appendix IV)), carbamates (carbaryl, methomyl), organochlorines (endosulfan, lindane), pyrethroids (alphamethrin, cyfluthrin, cypermethrin, deltamethrin, permethrin) to the biopesticide *Bacillus thuringiensis*. Against cutworms the list of cleared pesticides for tomato is limited to carbaryl, cyfluthrin, endosulfan, lindane, parathion and phosalone (D.G.P.P.A., 1980; 1984 and appendices).

Other control methods have been investigated as alternatives to chemical control against greenhouse caterpillars throughout the world.

Apart from *B. thuringiensis*, biological control alternatives include the use of virus, insect-parasitic nematodes (Payne, 1986) and, eventually, the use of parasitic wasps either against eggs (*Trichogramma* sp.) or larvae (Foster, 1986b).

Viruses belonging to the family *Baculoviridae* (sub-groups A and B (Payne & Kelly, 1981)) have been investigated against greenhouse caterpillars (Payne, 1986). Recent attempts include the use of *Spodoptera exigua* Nuclear Polyhedrosis Virus (SeNPV) against *S. exigua* on several glasshouse crops in the Netherlands (Smits *et al.*, 1987b); the use of a Granulosis Virus (GV) of *Lacanobia oleracea* (LoGV) in Scotland (Foster & Crook, 1983); and in France the use of *Spodoptera littoralis* NPV, specifically for *S. litorallis* control, and *Mamestra brassicae* NPV, which, unlike the previous one, is not specific to *M. brassicae* but is also effective against *Helicoverpa armigera, Spodoptera exigua, Autographa gamma, Lacanobia oleracea* and *Noctua pronuba* (Anonymous, undated; Payne, 1986; Biache, 1987). However, *Agrotis segetum* is relatively resistant to the MbNPV Virus (Payne, 1986).

Sunlight, particularly the ultraviolet component, seems to be the major inactivation factor affecting insect viruses under natural conditions (Jaques, 1985). As a result of partial absorption of ultraviolet radiation by greenhouse covering material, greenhouse crops are regarded as a better environment for virus control agents since inactivation is not so fast as under field conditions

(Smits *et al.*, 1987b).

Caterpillar infection with virus occurs after ingestion of the polyhedral inclusion bodies (PIBs) with food. Caterpillars usually continue feeding until they die, 3-4 days after infection (Payne, 1986). As a result treated caterpillars can produce crop damage. This can cause problems to the practical application of viruses on high value crops with low damage thresholds (Smits *et al.*, 1987b). However, Bues *et al* (1987) reported satisfactory results from the south of France against *H. armigera* on greenhouse tomatoes using a NPV formulation available on the French market. According to the manufacturers a rate of 10^{13} PIBs / ha every 7 days from the beginning of egg laying achieves a control level equivalent to that of current chemical control schemes (Anonymous, undated).

Insect-parasitic nematodes have been employed against cutworms in lettuce crops either under glasshouse conditions (*Agrotis ipsilon* controlled by *Steinernema feltia* (=*Neoaplectana carpocapse*) (Laumond, 1973)) or field conditions (*Agrotis segetum* controlled by *Steinernema bibionis* (Lössbroek & Theunissen, 1985)). In countries like The Netherlands, where these nematodes have been considered exempt of the normal requirements for pesticide registration, they are already commercially available (Payne, 1986).

Several parasitic wasps have been recorded associated with the caterpillar species causing problems in greenhouses.

Recently, Caballero *et al.* (1989) discussed the parasitoid species affecting *A. segetum* in Spain and Inserra & Calabretta (1985) indicated the parasitoid species attacking *S. littoralis* and *C. chalcites* in Italy. However, attempts to use them in greenhouses are not known. By contrast, the use of egg parasitoids (*Trichogramma* spp.) against tomato moths under field conditions have been widely investigated. In Portugal, Meierrose & Araujo (1986) found local *Trichogramma* strains able to parasitise efficiently *H. armigera* eggs on tomato crops under field conditions and well adapted to high temperatures. But their performance under greenhouse conditions are unknown.

There is considerable variation in resistance to caterpillars amongst tomato cultivars (Juvik *et al.*, 1982; Lal, 1985; Kashyap & Verma, 1986). Such differences seem to be explained by the concentration levels of the glycoalkaloid α-tomatine present in the different cultivars (Stevens & Rick, 1986). Unfortunately, information about the α-tomatine content (or the relative resistance level) of current cultivars is not available to growers to be used as a decision factor in regions where caterpillars are major pests.

Potential new chemical options for caterpillar control include the use of insect growth regulators (IGRs) (diflubenzuron and related benzoylphenyl ureas (Jarrett, 1985a; Guyer & Newmann, 1988; Aldebis *et al.*, 1988)) and the use of avermectins (AVM) (Dybas & Green, 1984; Anderson *et al.*, 1986; Christie & Wright, 1988; Dybas, 1988). New

a.i. belonging to the insecticide groups already available have also been developed and the soil pyrethroid tefluthrin, active against cutworms (Jutsum *et al.*, 1986), is just an example. At the moment avermectins and tefluthrin are still under development and not yet available in many countries (not cleared yet in Portugal) and diflubenzuron is not cleared to be used on Portuguese greenhouse crops.

Finally, deleafing and hand-picking have been used as a cultural control method to eliminate caterpillar eggs or larvae from greenhouse crops, with poor results (Foster, 1980).

Since the strategy to treat only after caterpillar attack detection is recommended (Fig. 6.2), tactics for control and application methods are discussed next.

Treatments should be performed as earlier as possible against emerging neonate larvae or as soon as larvae are detected because the most significant damage is usually not performed in the first larval phases, larvae are usually easier targets when young and are more susceptible to pesticides. As no biological control is performed at present in Portugal, the choice of pesticides does not include side-effects on beneficial organisms and is mainly dependent on perceptions about relative efficacy of different a.i., harvest interval (H.I.) and price.

Ledieu (1978) compared several insecticides for caterpillar control in greenhouses and concluded that methomyl,

chlorpyrifos and methamidophos were significantly more potent than acephate, carbaryl, permethrin and endosulfan. Recently Inserra & Calabretta (1985) reported good results achieved with methomyl and deltamethrin against greenhouse noctuids in Sicily, while acephate had a lower efficacy. Under Portuguese clearance conditions deltamethrin has a 2 days H.I.; methomyl, carbaryl and methamidophos have a 7 days H.I.; chlorpyrifos 14 days H.I.; acephate 21 days H.I. and endosulfan 28 days H.I.

During harvesting periods if growers face attacks by leaf or fruit caterpillars they still have some choice amongst pyrethroids (deltamethrin, cyfluthrin, cypermethrin and permethrin - 2 days H.I.; alphamethrin - 4 days H.I.), OP's (malathion - 1 day H.I.; etrimfos - 3 days H.I.; mevinphos - 4 days) and *Bacillus thuringiensis* (0 days H.I.). However, against cutworms the choice is very much restricted to the pyrethroid cyfluthrin (2 days H.I.) or to carbaryl (7 days H.I.) if the grower can afford delaying harvest some days.

If the attack persists, treatments should be performed every 14 days during the period of attack unless the attack is very intense and/or the pesticide residue is washed out by other sprays; in that case treatments should be performed on a weekly basis while necessary. The evolution of infestations and treatment efficacy should be checked carefully during regular crop monitoring. At the end of the season if the infestation was important growers should consider soil sterilisation in order to eliminate

pupae or overwintering larvae, reducing the risks of an attack earlier next season or crop. However, methyl isothiocyanate soil sterilants (like dazomet) are not very effective (Foster, 1986a & b), methyl bromide is very expensive and probably unjustifiable and, under these circumstances, insect-parasitic nematodes could probably be a very effective control agent.

When caterpillar populations are submitted to very intense pesticide selection pressure resistant strains become dominant very rapidly. Therefore, growers should alternate pesticides with different modes of action among the several a.i. options they have in order to delay this risk.

In northern European countries the wide adoption of biological control methods justifies the use of *Bacillus thuringiensis* for caterpillar control in spite of its higher cost compared with non-selective insecticides (Foster, 1986b). However, its advantages (selectivity and absence of residue problems on crops (Jarrett, 1985b)) are less attractive to growers under pure chemical control schemes. As the bacterial toxin needs to be ingested to be effective, good spray coverage is essential and frequent applications required (Payne, 1986; Foster, 1986b).

Once caterpillars ingest the toxin they stop feeding (the toxin paralyses the mouthparts and gut muscles) but continue active and death may take up to 7 days (Jarrett, 1985b). If growers are unaware of that then they can misjudge the efficacy of the treatment, particularly if a

rapid knockdown effect was expected. This factor may be another disadvantage for the use of *B. thuringiensis* formulations when compared with chemical control, as Payne & Jarrett (1984) recognised. Furthermore, the commercial products available on the Portuguese market, thuricide and bactospeine (based on *B. thuringiensis* var. *kurstaki* strain HD-1) are not equally effective to all the species affecting greenhouse crops, demanding from the grower the correct identification of the species involved in each case.

The commercial formulations mentioned above have good activity against *H. armigera* (Payne & Jarrett, 1984). However, *A. gamma* is less susceptible and the activity of those formulations against *M. brassicae*, *A. segetum* and *S. littoralis* is very low (Payne & Jarrett, 1984; Jarrett, 1985b). As has been observed with chemical pesticides, the larval susceptibility to the bacterial toxin decreases during later instars, justifying applications as early as possible (Jarrett & Burges, 1982; Jarrett, 1985b).

For cutworm control treatments against young larvae (two first instars) should be done with H.V. spray applications to achieve the best possible leaf coverage (if fogging machines are used systemic pesticides should be selected; otherwise, protection of the underside of the leaves will be very poor). Later, when cutworms adopt their characteristic behaviour, soil drenches can be applied along the line of the plants (some growers do it through the irrigation system - see 5.3.6.4). Alternatively, or in

addition, growers can apply bait pellets (see 5.3.6.4).

For leaf caterpillar control H.V. sprays are recommended to achieve the best possible leaf coverage. If growers use fogging machines systemic insecticides would increase larval control on the underside of the leaves. Furthermore, growers should be aware that different additives used to improve fogging characteristics (as discussed at 5.3.6.5) cause quite different residues on the crops (Powell *et al.*, 1984), the same being true for different pesticide formulations (Lindquist & Powell, 1981). The best deposit on plants (meaning higher mortality of caterpillars) was achieved with the "VK - 2" carrier (PULSFOG ^{R}) and wettable powder formulations (Lindquist & Powell, 1981; Powell *et al.*, 1984).

Applications of *B. thuringiensis* with fogging machines also result in very poor deposition of bacteria on the underside of the leaves (Burges & Jarrett, 1979). As applications of *B. thuringiensis* can be active for more than 28 days, if the residue is not washed out by H.V. sprays (Jarrett, 1985b), eventually caterpillars eat through the leaf and ingest the bacterial toxin (Burges & Jarrett, 1979). However, H.V. fungicide sprays are regularly applied on greenhouse crops and can reduce other pesticide residues dramatically (*B. thuringiensis* included).

The above discussion for leaf caterpillars is also valid for fruit caterpillars with the added remark that spray timing should be even more precise since caterpillars are

only exposed to pesticide residues during a few days after hatching, while feeding on leaves. After, they bore into fruits and become quite inaccessible to pesticides. Spraying is made even more difficult by the fact that eggs are laid singly, scattered across the crop and, as a result, attacks are often only detected after fruit infection.

6.3 - FUTURE PROSPECTS

The development of an expert system to describe the decision processes adopted by growers to control pest problems in greenhouses could be performed by expanding the present prototype structure created for the case studies used to illustrate its potential (sections 6.2.1 and 6.2.2).

Apart from tomato, such enlargement would include other crops like green beans and melon (eventually all the major crops grown in greenhouses, indicated in Chapters 3.3 and 5.3.4.1), and for each crop and major pests pointed out by growers (Chapter 5.3.6) a decision tree similar to those presented in Figs. 6.1 and 6.2 would be the basic structure of the descriptive model.

The hypertext facilities of the **KnowledgePro** shell, as demonstrated in the case studies, are an easy way to display additional information related to biological characteristics of the pests and crops as well as detailed

explanations of control methods and decisions recommended by the system.

Therefore, an expanded version of the present expert system prototype seems to have the potential to provide relevant technical information to growers or their advisors, the limiting factor being represented by the availability of microcomputers.

On the other hand this system, while structuring the decision problem and describing the decision-making process, highlights only the information needed by growers to solve the particular pest problem under consideration. Those two reasons (usefulness of information, and consistency and soundness in their use) probably represent the greatest value of using an expert system approach in describing the decision processes adopted against greenhouse pests. Furthermore, such a system could be used as a training facility in professional courses or seminars for growers and new extension agents. It could also be a tool to teach and illustrate principles of the decision--making process in pest control for agricultural students.

At the moment in the West growers' cooperatives and some growers organised in groups for production and marketing reasons already have microcomputer facilities for other management purposes like accounting, while in the Algarve the regional services of the Ministry of Agriculture have good computing facilities. Since the necessary technology is already available at regional level the system could

then be tested with local growers and validated for use as a prescriptive control tool under local conditions. The system could eventually be used by local extension agents (either from public services or private) and by innovative growers.

Regularly updated versions would be necessary to include new information about control options (particularly cleared pesticides or their side-effects if IPM schemes become adopted), eventually about new pest problems and crops, and about special difficulties with current pests (like resistance situations). The update frequency would be dependent on the rate of change of the factors listed above.

Portuguese agricultural extension services were traditionally considered weak both in personnel and in terms of links with researchers and farmers (Kavalsky & Agarwal, 1978). In spite of recent improvements in the extension services these services are still considered, in general, ineffective in identifying farmer needs and disseminating research results (Monke *et al.*, 1986; Pearson & Monke, 1987). The rapid expansion of the greenhouse production system has created additional difficulties for the extension services to provide the growers with an effective supporting service.

The development and adoption of an expert system tool in Portugal, as discussed above, could then be seen as an useful innovation to help deliver relevant technical

information to growers, and in a broader sense, to improve pest control practices in greenhouse crops.

7 - CONCLUSIONS AND RECOMMENDATIONS

7.1 - INTRODUCTION

The work presented in this thesis is based on the assumption that any improvement in crop protection at the farm level can only be achieved if the technical recommendations provided to the growers improve their perceptions of existing pest problems and available control options and take account of growers' objectives. This implies that research and extension programmes in crop protection should start with a precise definition of the pest problems under real farm circumstances, based on the understanding of farmers' perceptions and on the identification of information gaps existing at research, extension or farm level.

One method to perform this task is through a "soft" system analysis approach (as discussed in Chapter 4.3), by synthesising and structuring already existing information on the biology and technology components, and basing the descriptive analysis related to the management component (as illustrated in Fig. 4.3) on a survey questionnaire of growers. This was the methodological approach used in this thesis.

It can be argued that growers' perceptions may or may not reflect the real pest problems or control options, and in this case the definition of key pest problems based on growers' perceptions can be distorted. However, the chances of that event are only expected to be relevant with new growers, with new pest problems previously unknown in the region under study or with diseases not having a very specific symptomatology. Otherwise, this risk is assumed to be relatively low, particularly when growers indicate pest problems widely known and frequent/abundant in the crop under consideration or other crops of the region.

Furthermore, growers will react to pest problems according to the way they perceive them, and poor or incorrect perceptions can be a major cause of control decisions resulting in unsactisfactory outcomes. Because of that, the knowledge of growers' perceptions is very important when pest constraints are considered (even if wrong). It may also help to understand the reasons for any apparently strange or unapproved pesticide application or any other practice. Finally, growers' perceptions can always be checked against other available information from independent and reliable sources (expert opinions, technical reports, scientific records, if available), tested during the survey questionnaire if that is considered necessary, or verified during the subsequent research phases performed after the descriptive phase.

7.2 - CONCLUSIONS

7.2.1 - Insight into the greenhouse production system in Portugal

Tomato continues to be the major greenhouse vegetable crop in both regions under study (Algarve and the West), being produced mainly as an autumn-winter crop. In the Algarve growers alternate tomato mainly with melon, green bean or sweet pepper crops. In the West tomato is usually followed by a spring green bean crop. Strawberries have recently been regarded as an alternative crop for greenhouse production by some growers in both regions, and a few growers in the Algarve are checking the potential of the banana crop under greenhouse conditions.

The cultivars adopted in both regions are the same for most of the crops. For the tomato crop growers in the Algarve prefer the cultivar Carmello while in the West Dombito and Dombello are the preferred cultivars. This difference in cultivar preferences could result from salinity problems faced by growers in the Algarve region. The majority of growers prefer to produce their own seedlings but in the Algarve some demand already exists, specially for tomato and melon seedlings. Supply is being provided by better equipped local growers who also run nursery facilities.

Some cultural practices differ between the regions, like fertilisation guidance through soil analysis, irrigation

and top-dressing frequencies and the use of plant growth regulators on tomato. Yield levels reported from the West are higher than those from the Algarve, at least for the tomato and green bean crops.

Growers in the West moved to the industry mainly in the middle 1980's, while in the Algarve the big expansion was in the late 1970's and early 1980's, and the proportion of young growers in the West is bigger than in the Algarve. They profited from the Algarve experience but also tried to adapt solutions to their particular situations, as demonstrated by the "Parral" greenhouse structure.

7.2.2 - Growers' perceptions of pest problems

The weed problems indicated by growers for the different crops are almost the same and are basically represented by species of the local flora with very efficient reproductive mechanisms, either by seeds (*Solanum nigrum*, *Chenopodium album*, *Amaranthus retroflexus*) or vegetative organs (*Oxalis pes-caprae*, *Cyperus* spp., *Convolvulus arvensis*, *Cynodon dactylon*), or species repeatedly inoculated in the soil probably through manure (as pointed out for *Galium aparine*).

However, the regional pattern of weed importance is different between the two regions: *Oxalis pes-caprae*, *Solanum nigrum*, *Chenopodium album* and *Cyperus* spp. were the major weeds indicated by growers in the West while in the Algarve growers reported mainly *Galium aparine*, *Amaranthus*

retroflexus and *Oxalis pes-caprae*. A few growers in the Algarve indicated the occurrence of *Orobanche* spp. infestations on tomato, which can become an important weed problem in the future.

Diseases are normally perceived by the growers as the key pest problem on greenhouse crops and their control determines the strategies predominant in crop protection. Arthropod pests are usually considered less important than diseases.

On **tomato**, grey mould and late blight are the major air--borne diseases in both regions. Root-knot nematodes seem to be the most important soil pests, specially in the Algarve. About arthropod pests, caterpillars are the major problem in both regions. Spider mites were indicated also as an important pest problem in the Algarve, and only a few growers in both regions reported whitefly.

On **melon** *Fusarium* wilt is the major pest problem faced by growers. Root-knot nematodes are another important soil pest. Powdery mildew is the major air-borne disease. Spider mites are the major arthropod pest and a few growers pointed out whitefly.

The key pest problem on **green beans** is grey mould, in both regions. In the West *Fusarium* root rot is also becoming an important constraint to the crop. Spider mites are the major arthropod pest on this crop.

On **sweet pepper** the predominant arthropod pest problems in

the Algarve are aphids and spider mites, and powdery mildew and viruses are the predominant diseases. In the West they seem to be respectively caterpillars and powdery mildew.

On cucumber the predominant pest problems are powdery mildew, spider mites and aphids, in both regions. On lettuce *Sclerotinia* disease/grey mould complex and root--knot nematodes are the predominant pest problems in the West.

During the nursery period growers also face several pest problems affecting seedlings. In the Algarve the predominant problems are soil-borne fungi causing root rots, tomato late blight and slugs/snails. In the West growers reported the same diseases, but instead of mollusc attacks growers were concerned about leafminer and whitefly attacks.

7.2.3 - Growers' perceptions of control options

Weed problems in greenhouse crops are solved with two major strategies: hand weeding/hoeing, performed two or three times throughout the season, or plastic mulching of the soil along the line of the plants, which is usually associated with drip irrigation. However, in the long term the hand weeding/hoeing strategy can suffer from labour constraints. Furthermore, shoots of *Cyperus rotundus* have been reported as being able to penetrate polythene with a thickness of 0.127 mm (Henson & Little, 1969), which

suggests that plastic mulching can give poor results if high infestations of this weed occur. A small number of growers in the Algarve apply herbicides (metribuzin) after tomato transplant. The natural vegetation occurring outside, around greenhouses, is generally destroyed by paraquat applications or hand weeding/hoeing.

The control options adopted by growers against diseases and arthropod pests are mainly dependent on chemical control.

The usual strategy employed is based on scheduled treatments against key diseases, the spraying interval being dependent on weather conditions, and either opportunistic treatments or treatments based on pest presence against arthropod pests. The decision factors adopted by growers to begin spraying against the same pest problem vary widely. Growers reaction to the increase in importance of pest problems seem to be the usual reduction of the spraying interval and/or increasing the recommended concentration.

Normally growers rotate the pesticides they employ against the major pest problems throughout the season. New pesticides are widely used and in some cases growers made pesticide applications with a.i. uncleared for use on that crop. In a few cases growers even spray a.i. unauthorised in the country, which they get illegally, trying to solve difficult pest problems like bacteria attacks.

In the West growers spray mainly with the hydraulic knapsack sprayer at the beginning of the crop and later

change to knapsack mistblowers, while in the Algarve the majority of the growers always spray with tractor-mounted sprayers. Some growers are adopting fogging equipment for pesticide application in order to cut down spraying time and labour needs.

Growers' perceptions of other control methods vary with the methods and sometimes with the region.

Biological control is mainly unknown or regarded as not acceptable by the majority of the growers in both areas. However, 13% of the surveyed growers in the West and 17% in the Algarve are already receptive to the idea of biological control and will try this technique when biological control agents become available. A constraint to this technical approach can be the fact that, at present, the majority of the growers are unlikely to accept control strategies involving more monitoring time than is currently practised.

Solarization is mainly unknown or regarded as not acceptable by the majority of the interviewed growers in the West. Many growers mentioned their concern about the fact that the necessary delay of 4-6 weeks between two crops during summer to perform the technique could have economic disadvantages, which could make solarization unattractive. In the Algarve 10% of the interviewed growers have already used or are going to use it, suggesting that innovative growers and some early adopters have already picked-up the technique. This difference between the two regions must be due to the recent research

and extension effort of the regional services of the Ministry of Agriculture in the Algarve, while in the West research is only beginning.

Resistant cultivars are not considered an alternative control option by half of the interviewed growers. Instead of considering the resistance pattern of the cultivar during the selection process, they claimed that cultivars are selected only by their productivity and market acceptability. Nevertheless, the most popular cultivars (specially with tomato) are resistant to some pest diseases.

7.2.4 - Growers' assessment of the pest control results achieved and their improvement

The majority of the surveyed growers are happy with the efficacy of the pesticides they employ. However, there are some pest problems against which growers never achieved a satisfactory control or for which it is difficult to obtain good control, like grey mould and bacteria on tomato, *Fusarium* wilt on melon, and *Fusarium* root rot and grey mould on green beans. A reduction of pesticide efficacy was only reported by one interviewed grower against grey mould on tomato.

In general terms growers perceive pesticide efficiency as being high or very high. This fact, linked with the

perception of pesticides as an insurance instrument to prevent sometimes serious losses, explains the control strategies adopted by growers in spite of pesticides being assessed as expensive or very expensive production factors.

Concerning pesticide application methods, the majority of the interviewed growers are satisfied with the efficacy achieved. However, 50% of them in the West and 41% in the Algarve consider the application costs high or even extremely high.

Growers seem to observe the harvest interval mainly for insecticides and acaricides. However, if an intense pest attack occurs close to the harvest period in some cases the harvest interval is not respected.

The majority of the surveyed growers consider the technical information made available to them insufficient. They think the Ministry of Agriculture should be the major information provider and in the West they accept the idea of paying for relevant information, while in the Algarve growers oppose that idea. At present the major information providers are pesticide dealers, Ministry of Agriculture, pesticide companies, cooperatives and other growers or friends.

Growers are expecting the occurrence of new pest problems in the near future. However, they do not expect further difficulties in the near future in achieving good control of current pest problems, suggesting that they do not perceive resistance problems as a threat to the industry. In order to improve pest control practices in the future

most growers perceive as necessary: a) more information on pesticides and application methods; b) more information on pests and crop losses; and c) more effective pesticides.

7.3 - RESEARCH AND EXTENSION RECOMMENDATIONS

Research targets concerning pest control on greenhouse vegetable crops should include:

- checking growers' perceptions about a number of pest problems like: the occurrence of downy mildew of cucurbits, mentioned by growers in the Algarve; the occurrence of cladosporiose on tomato, mentioned in both regions; identifying the blight pest problem on sweet pepper (occurrence of *Phytophthora capsici*?) as well as on green beans (a bacterial problem?);

- identifying the species of soil-borne fungi involved in root rots and wilts (*Fusarium*, *Pythium*, *Phytophthora*, etc.) on melon, green beans, cucumber and tomato as well as on nurseries;

- study the possible existence of grey mould resistance to benzimidazoles and dicarboximides, in order to give precise indications for grey mould management on tomato at the farm level. Gullino & Garibaldi (1986) had developed a simple rapid test to check the existence of resistance, which they claimed has been effectively used in Italy by the extension services to

give advice to individual growers;

- study the population dynamics of greenhouse whitefly in order to understand why this pest is perceived by growers as frequent but not as one of the important pest problems, in contrast with the situation in almost every country with this pest problem (e.g. many Mediterranean countries and Japan);

- study the population dynamics of greenhouse caterpillars and the efficacy of alternative control methods (like viruses) in order to avoid preventative sprayings with broad spectrum insecticides;

- study the population dynamics of greenhouse spider mites and develop or adapt already available mass rearing units for *Phytoseiulus persimilis* which can be handled by the regional services from the Ministry of Agriculture, cooperatives, or even groups of growers;

- continue the solarization research programmes, which have been done in the country for control of weeds and soil-borne pest problems, and study its integration with other control methods.

- development of efficient ways to provide growers with the already available technical information and new research data, in a friendly, ready-to-use format.

Extension targets should cover the information gaps mentioned by growers and provide already available

technical recommendations on:

- production aspects, like fertilisation (Simões, 1987), recommended cultivars for the area, plant management techniques;

- relevant biological characteristics of the major pest problems and the losses they cause;

-detailed information on pesticide efficacy, mode of action, resistance problems and application methods as well as on safety and residue aspects of pesticide use;

- alternative control methods, including solarization, resistance characteristics of the cultivars, cultural practices, biological control agents, indicating the advantages and inconvenients of each method.

In this thesis an expert system for use by the growers' advisors or by the growers themselves is proposed. By structuring the decision-process and displaying the relevant technical information it could help the growers to improve their pest management practices.

ACKNOWLEDGEMENTS

I would like to express my gratitude to my supervisor Dr John Mumford for his guidance, help and interest throughout this study.

I would also like to acknowledge all the advice and assistance provided by Dr Geoff. Norton and Profs Michael Way and Pedro Amaro during this project.

The project was funded by Comissão Permanente INVOTAN (Portugal) to whom I am very grateful.

I am thankful for all the advice provided in the first phase of the project by Dr N. W. Hussey and Engo Fernando Magalhães.

I am grateful to all the growers contacted, who kindly answered my questions and allowed me to share their concerns about pest control problems. During the field work phase of the project the helpful support of Engos Luis Trindade and Rui Delgado, E.T.A.s Rui Silveira and Miguel Rato and Mr Henriques (in the West) and Dr Adelaide Henriques, Engo Fernando Severino, E.T.A.s Manuel Victorio and Jose Fernandes (in the Algarve) was greatly appreciated.

I wish to thank all my Portuguese colleagues Profs A. Silva Fernandes and A. Monteiro, Engos Passos de Carvalho, C. Bugalho Semedo, Julia Ferreira, Flavia Ramos, Cristina

Lança and Jorge Ferreira and many others who have not been mentioned but who have provided technical information.

Finally, I would like to thank all the friends and colleagues in Silwood Park who helped in making the stay enjoyable, in particular Julia Compton, Roger Day, Hefin Jones, Jonathan Knight, Peter Odiyo, Lori Peacock, Vania Pivello, David Wareing and Conrad Warwick.

To Ana I owe all the attempts to transform doubts and anxieties into incentives to continue, with a gracious touch of class.

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APPENDICES

APPENDIX I

1.1 - Table A - CHANGES IN GREENHOUSE AREA BY COUNTRY.

Country	year	area of greenhouses (ha) in the country	plastic houses	per crop		source	remarks
EUROPE							
Austria	1964	?		veget.	60	Dalrymple,1973	
	1966	?		veget.	73	" "	
	1968	?		veget.	87	" "	
	1970	?		veget.	96	" "	
	1971	?		veget.	100	" "	
	1983	2,000				Porcelli & D'Amore,1986	
Belgium	1950	688				Dalrymple,1973	
	1960	965				" "	
	1966	1,160				" "	
	1969	1,232				" "	
	1974	1,520	51	veget.& fruit. ornam.	1,240 280	Sheard,1974	
	1981	2,849		tom. cuc. let. other	1,070 65 1,380 334	Pelerents, 1986	
	1982	2,636		tom. cuc. let. other	1,062 69 1,200 305	Pelerents, 1986	
	1983	2,721		tom. cuc. let. other	978 85 1,200 305	Pelerents, 1986	Porcelli & D' Amore (1986) refer 550 ha of low plastic tunnels
Bulgaria	1955	5				Dalrymple,1973	
	1957	8				" "	

Table A - (cont.)

Country	year	area of greenhouses (ha) in the country	plastic houses	per crop		source	remarks
Bulgaria (cont.)	1963	36				Dalrymple,1973	
	1965	144				" "	
	1967	390				" "	
	1969	600				" "	
	1970	800	200			" "	
	1980		900			Garnaud,1984	
	1983	1,850	1,000			Porcelli & D' Amore,1986	12,000 ha of low plastic tunnels
Czechos-lovakia	1970	600				Dalrymple,1973	
	1971	500	100			Gardner,1974	rough estimate
	1984	270	158			Porcelli & D' Amore,1986	
Denmark	1960	359		veget.	185	Dalrymple,1973	
	1965	516		veget.	209	" "	
	1968	551		veget.	230	" "	
	1970	570		tom.	117	" "	
				cuc.	54		
				let.	29		
				melons	16		
				oth. veg.	17		
				ornam.	337		
	1979	900	20	flowers	650	Lenteren & Woets,1980a	
				veget.	250		
Finland	1969	305		tom.	123	Dalrymple,1973	
				cuc.	42		
				let.	5		
				oth. veg.	11		
				ornam.	124		
	1973	310		veget.	190	Markkula, 1973	
				flowers	120		

Table A - (cont.)

Country	year	area of greenhouses (ha) in the country	plastic houses	per crop		source	remarks
Finland (cont.)	1979	386	100	tom. cuc. oth. veg. ornam.	156 61 69 100	Markkula & Tiitanen,1980; Lenteren & Woets,1980a	
France	1961	?		veget.	120	Dalrymple,1973	
	1962	?		veget.	160	" "	
	1964	?		veget.	250	" "	
	1966	?		veget.	590	" "	
	1968	1,205		veget. ornam.	800 405	" "	
	1970	?	350	veget.	1,100	" "	
	1974	1,500	860	veg. & fruit ornam.	1,100 400	Sheard,1974	
	1980		4,000			Garnaud,1984	12,000 ha of low plastic tunnels
	1983	7,000	5,000			Porcelli & D' Amore,1986	19,000 ha of low plastic tunnels
	1984	9,000		veget. ornam.	6,500 2,500	Nisen *et al.*,1988	20,000 ha of low plastic tunnels
East Germany	1956	?	166	veget.	166	Dalrymple,1973	
	1970	?	200			" "	
	1983	1,140	430			Porcelli & D' Amore,1986	
West Germany	1956	?		veget.	800	Dalrymple,1973	
	1962	?		veget.	850	" "	
	1966	1,820		veget. ornam.	730 1,090	" "	

Table A - (cont.)

Country	year	area of greenhouses (ha) in the country	plastic houses	per crop		source	remarks
West Germany (cont.)	1970	2,350	212	veg. & fruit	860	Dalrymple,1973	
				ornam.	1,490		
	1975	1,340	460	flowers	890	Lenteren & Woets,1980a	
				veget.	450		
	1979	2,300				Sheard,1981	
	1983	3,900	400			Porcelli & D' Amore,1986	1,000 ha of low plastic tunnels
Greece	1966	250	250			Dalrymple,1973	
	1969	1,267				Michelakis, 1983	almost all in plastic
	1972	1,500	1,500			Dalrymple,1973	
	1979	3,292				Michelakis, 1983	almost all in plastic
	1983	3,500				Argyriou,1986	almost all in plastic. Porcelli & D'Amore (1986) refer 7,000 ha of low plastic tunnels
(Crete)	1969	177				Michelakis,1983	
	1971	286				Dalrymple,1973	
	1979	1,233				Michelakis,1983	
	1982	1,355		tom.	469	Kozirakis,1983	
				cuc.	660		
				other veget.	156		
				flowers	70		
	1983			banana	60	Nisen *et al.*,1988	

Table A - (cont.)

Country	year	area of greenhouses (ha) in the country	plastic houses	per crop		source	remarks
Hungary	1960	25				Dalrymple,1973	
	1969	800	700			" "	
	1971	1,100	1,000			Gardner,1974	rough estimate
	1983	5,200	5,000			Porcelli & D' Amore,1986	
Ireland	1960	76				Dalrymple,1973	
	1962	87				" "	
	1964	100				" "	
	1966	121				" "	
	1968	156				" "	
	1970	186		tom. cuc. flowers let.	177 9 44	" "	lettuce as a winter crop in 25% of tomato area, which is a spring--summer crop
	1974	203		tom. cuc. sweet- pepper ornam.	162 41 	O'Reilly,1974	
	1979	220	20	flowers veget.	190 30	Lenteren & Woets,1980a	
Italy	1960	624		veget.	238	Dalrymple,1973	
	1964	2,408	1,193	veget.	1,432	" "	
	1969	5,141	3,995	tom. pepper marrow eggpl. cuc. let. oth.veg. orn. & tobac.	2,120 521 409 119 100 97 354 1,421	" "	

Table A - (cont.)

Country	year	area of greenhouses (ha) in the country	area of greenhouses (ha) plastic houses	area of greenhouses (ha) per crop	source	remarks
Italy (cont.)	1978	10,765			Lenteren & Woets,1980a	
	1980		14,900		Garnaud,1984	10,000 ha of low plastic tunnels
	1982	16,266		tom. 4,700 stawb. 3,346 sweet-pepper 2,835 eggpl. 1,162 cuc. 596 melon 527 let. 438 other 2,662	Garibaldi & Corte,1986	almost all in plastic; 14,000 ha of low plastic tunnels
	1983	22,000	19,500		Porcelli & D' Amore,1986	16,000 ha of low plastic tunnels
Nether-lands	1912	194		veget. 109 fruit 85	Dalrymple,1973	
	1940	2,367		veget. 1,214 fruit 866 ornam. 287	" "	
	1950	2,342		veget. 1,270 fruit 789 ornam. 283	" "	
	1960	4,048		veget. 3,077 fruit 474 ornam. 498	" "	
	1965	5,960		veget. 4,742 fruit 316 ornam. 902	" "	
	1970	7,245		tom. 3,300 cuc. 900 other veget. 1,174 fruit 211 ornam. 1,660	Bravenboer,1970; Dalrymple,1973	

Table A - (cont.)

Country	year	area of greenhouses (ha) in the country	plastic houses	per crop	source	remarks
Netherlands (cont.)	1971	7,368		veget. 5,276 fruit 193 ornam. 1,899	Dalrymple,1973	
	1972	7,783		veget. 5,033 fruit 167 ornam. 2,183	" "	
	1974	7,360	8	tom. 2,950 other veg.& fruit 2,510 ornam. 1,900	Sheard,1974	
	1975	7,500		tom. 2,200 flower 2,800 cuc., let., sweet-pepper 2,500	Lenteren *et al.*,1976	
	1976	7,900		tom. 2,040 cuc. 720 sweet-pepper 160 other veget. 1,780 flower 3,100 fruit trees 100	Woets,1976; Lenteren *et al.*, 1980a	
	1978	?		tom. 2,000 other veget. 2,600	Lenteren *et al.*, 1980a	
	1979	8,630			Lenteren & Woets,1980a	
	1983	10,150	150		Porcelli & D' Amore,1986	50 ha of low plastic tunnels
	1985	8,000		ornam. 4,109 tom. 1,959 other veget. 1,909	Minkenberg & Lenteren,1986	

Table A - (cont.)

Country	year	area of greenhouses (ha) in the country	plastic houses	per crop		source	remarks
Norway	1959	145		veget.	105	Dalrymple,1973	
				ornam.	40		
	1969	190	17	tom.	63	" "	
				cuc.	21		
				let.	11		
				oth. veg.	17		
				ornam.	78		
	1980	100				Lenteren & Woets,1980a	rough estimate
	1983	200				Porcelli & D' Amore,1986	
Poland	1950	113				Dalrymple,1973	
	1960	202				" "	
	1965	276				Gardner,1974	rough estimate
	1970	435				Dalrymple,1973	
	1971	500	200			Gardner,1974	rough estimate
	1979	2,300	990			Lenteren & Woets,1980a	
Portugal	1970	81		flowers	81	Dalrymple,1973	180 ha of low plastic tunnels
	1977	400				Cunha,1979	rough estimate
	1982	800				Palma *et al.*, 1982	
	1983	1,100				Porcelli & D' Amore,1986	400 ha of low plastic tunnels
	1984	1,150		veget.	1,000	Nisen *et al*,1988	400 ha of low plastic tunnels
				ornam.	150		
	1986	1,220		veget.	1,020	Fonseca *et al*,1986	almost all in plastic
				ornam.	200		
Romania	1970	1,850	1,200	tom.	1,388	Dalrymple,1973	
				cuc.	222		

Table A - (cont.)

Country	year	area of greenhouses (ha) in the country	area of greenhouses (ha) plastic houses	area of greenhouses (ha) per crop	source	remarks
Romania (cont.)				peppers 93 others 147	Dalrymple,1973	
	1980	5,000	3,000		Lenteren & Woets,1980a	rough estimate
	1983	6,500	6,500		Porcelli & D' Amore,1986	
Spain	1967		343		Pedro,1984	487 ha of low plastic tunnels
	1970	300	300		Dalrymple,1973	area in continental Spain, only
	1971		1,820		Pedro,1984	3,300 ha of low plastic tunnels
	1976		5,762		Pedro,1984	3,320 ha of low plastic tunnels
	1980	32,295		melons 7,059 tom. 6,545 water-melons 5,773 sweet-pepper 4,434 green-beans 2,537 strawb 2,135 cuc. 2,127 eggpl. 809 marrow 720 let. 81 gherkin 65 peas 10	Hinton,1983	the area indicated for the country shows the area with "protected crops";some crops like stawberries,melons and water-melons are mainly produced on soil protected with plastic mulching
	1980		11,000		Garnaud,1984	4,000 ha of low plastic tunnels
	1983	38,872		water-melons 7,620 tom. 6,477 melons 6,312	Albajes,1986	the area indicated for the country shows the area with "prote-

Table A - (cont.)

Country	year	area of greenhouses (ha) in the country	area of greenhouses (ha) plastic houses	area of greenhouses (ha) per crop	source	remarks
Spain (cont.)				green-beans 6,006 sweet-pepper 5,514 stawb. 2,264 cuc. 2,109 eggpl. 840 other veget. 1,730	Albajes,1986	cted crops";some crops like strawberries, melons and water-melons are mainly produced on soil protected with plastic mulching
	1983	15,000	15,000		Porcelli & D'Amore,1986	area occupied by greenhouses and large tunnels, only; 6,500 ha of low plastic tunnels
	1984		15,596	veg. 14,236 ornam. 1,360	Nisen *et al.*,1988	6,000 ha of low plastic tunnels
(Almeria)	1968	30			Sargent,1986	
	1971	1,114			" "	
	1976	3,440			" "	
	1979	6,386			" "	
	1980	7,150			" "	
	1983	9,792			" "	
	1985	12,000			Steane,1985	one of world's greatest concentration
(Catalonia)	1984	?		melon 780 tom. 140 water-melon 109 marrow 55 green beans 45 ornam. 82	Bordas *et al.*,1985	

Table A - (cont.)

Country	year	area of greenhouses (ha) in the country	plastic houses	per crop		source	remarks
(Canaries)	1970	440-600				Dalrymple,1973	almost all in plastic
Sweden	1970	386				Dalrymple,1973	
	1973	415		tom.	87	Svenson,1973	
				cuc.	39		
				let.	39		
				oth. veg.	26		
	1979	415				Lenteren & Woets,1980a	
	1981	354				Ekelund & Lundahl,1984	
Switzerland	1965	?		veget.	32	Dalrymple,1973	
	1969	170		veget.	43	" "	rough estimate
	1983	250	50			Porcelli & D'Amore,1986	100 ha of low plastic tunnels
United Kingdom	1974	2,590	99	tom.	1,395	Sheard,1974	Spice (1974) estimated an area about 200 ha of plastic greenhouses and less than 1,000 ha of low plastic tunnels
				other veget. & fruits	625		
				ornam.	570		
	1979	2,650				Sheard,1981	
	1983	3,500	1,000			Porcelli & D'Amore,1986	1,000 ha of low plastic tunnels
	1984	2,576	348			Day,1985	
(England-Wales)	1954	1,919				Sheard,1981	
	1965	1,539				Sheard,1981	
	1966	1,583				Dalrymple,1973	

Table A - (cont.)

Country	year	area of greenhouses (ha) in the country	plastic houses	per crop		source	remarks
(England -Wales) (cont.)	1968	1,643				Dalrymple,1973	
	1970	1,704				" "	
	1971	1,727				" "	
	1974	1,860				Sheard,1974	
	1979	2,097	238			Lenteren & Woets,1980a	
	1981	2,163				Sly & Willians, 1985	
	1984	2,152	333			Day,1985	
(Scot-land)	1969	107		tom. cuc. let.	83 21	Dalrymple,1973	
	1974	?		tom.	27	Foster & Kelly, 1978	
	1976	121				Foster & Brodie, 1984	
	1977			tom.	26	Foster & Kelly, 1978	
	1980	80				Lenteren & Woets,1980a	
	1981	74		tom. let. oth. veg. ornam.	30 25 2 17	Foster & Brodie, 1984	
	1984	57	10			Day,1985	
	1985	54		tom.	21	Foster,1986a	
(North. Ireland)	1970	21		veget.	12	Dalrymple,1973	
	1984	?		veget.	18	Day,1985	

Table A - (cont.)

Country	year	area of greenhouses (ha) in the country	plastic houses	per crop		source	remarks
(Guernsey)							
	1970	463		tom.	360	Dalrymple,1973	
	1984	303		tom.	77	Day,1985	
				freesias	77		
(Jersey)	1970	45		tom.	31	Dalrymple,1973	
				let.	1.5		
	1984	46	5.5	tom.	23	Day,1985	
				flowers	15		
USSR	1965	?		veget.	479	Dalrymple,1973	
	1967	?		cuc.	430	" "	rough estimate
				onions	241		
				tom.	23		
				leafy greens	60		
	1968	?		veget.	1,078	" "	
	1970	?		veget.	2,166	" "	
	1971	3,500	2,000			Gardner,1974	rough estimate
	1978	7,000	2,000			Lenteren & & Woets,1980a	4,000 ha of low plastic tunnels
	1983	6,050	3,250	veget.	5,950	Popov,1983	
				ornam.	100		
	1984	7,000	5,600			Bry,1984	
Yugos-lavia	1970	121				Dalrymple,1973	
	1983	1,135	800			Porcelli & D' Amore,1986	100 ha of low plastic tunnels
NORTH AFRICA & MIDDLE EAST							
Algeria	1983	2,500	2,500			Porcelli & D' Amore,1986	
	1984	3,600		veget.	3,600	Nisen *et al*,1988	300 ha estimated of low plastic tunnels

Table A - (cont.)

Country	year	area of greenhouses (ha) in the country	plastic houses	per crop		source	remarks
Cyprus	1980	87				Garnaud,1984	
	1983	100	100			Porcelli & D' Amore,1986	400 ha of low plastic tunnels
	1984	166		veget. ornam.	134 32	Nisen et al,1988	515 ha of low plastic tunnels
Egypt	1984	126		veget.	126	Nisen et al,1988	
Israel	1970	?		veget.	25	Dalrymple,1973	almost all in plastic; 2,200 ha of low plastic tunnels
	1974	100				Sheard,1974	almost all in plastic; 2,000 ha of low plastic tunnels
	1979	1,600	1,420	flower veget.	1,000 600	Lenteren & Woets,1980a	
	1983	1,150	1,000			Porcelli & D' Amore,1986	
	1983	400		veget.	400	Nisen et al,1988	4,000 ha estimated of low plastic tunnels
Jordan	1983	500	500			Porcelli & D' Amore,1986	1,400 ha of low plastic tunnels
	1983	347				Nisen et al,1988	629 ha of low plastic tunnels
Lebanon	1980		60			Garnaud,1984	
	1983	200	200			Porcelli & D' Amore,1986	350 ha of low plastic tunnels
	1984	1,100		veget.	1,100	Nisen et al,1988	70 ha of low plastic tunnels
Malta	1974	14	9	tom. ornam.	6 8	Sheard,1974	

Table A - (cont.)

Country	year	area of greenhouses (ha) in the country	plastic houses	per crop		source	remarks
Morocco	1971	?		veget.	60	Dalrymple,1973	
	1980		204	tom.	120	Garnaud,1984; Hasnaoui,1984	
	1983		450			Garnaud,1984	
	1984	1,600		tom.	800	Nisen *et al*,1988; Hasnaoui,1984	
				other veget.	670		
				banana	80		
				ornam.	50		
Syria	1983	20				Nisen *et al*,1988	this data includes low plastic tunnels
Tunisia	1976	11				Aounallah,1984	
	1980		323			Garnaud,1984	
	1983	1,000	1,000			Porcelli & D' Amore,1986; Nisen *et al*,1988	rough estimate; 1,056 ha of low plastic tunnels
	1985	900		veget.	900	Nisen *et al*,1988	
Turkey	1968	600				Dalrymple,1973	
	1970	1,740				" "	
	1972	2,000				" "	
	1980		4,200			Garnaud,1984	
	1983	5,700	5,200			Porcelli & D' Amore,1986; Garnaud,1984	2,500 ha of low plastic tunnels
	1984	9,114		veget.	9,114	Nisen *et al*,1988	2,486 ha of low plastic tunnels
AMERICAS							
Canada	1966	239				Dalrymple,1973	

Table A - (cont.)

Country	year	area of greenhouses (ha) in the country	plastic houses	per crop		source	remarks
Canada (cont.)	1968	270				Dalrymple,1973	
	1970	302	69.5			" "	
	1979	200		cuc.	50	Lenteren & Woets,1980a; McClanahan,1980	
	1983	300	300			Porcelli & D' Amore,1986	100 ha of low plastic tunnels
USA	1889	361				Dalrymple,1973	
	1899	894		veget.	42	" "	
	1909	1,065				" "	
	1919	1,508				" "	
	1929	1,611		veget.	520	" "	
	1939	1,906				" "	
	1949	1,778		veget.	255	" "	
	1959	2,115		veget.	287	" "	
	1969	2,105		veget.	233	" "	
	1971	?		veget.	1,180	Cravens,1974	605 ha of the vegetable area are in plastic. Tomatoes are the major crop. Ohio the major producer
	1979	1,200	600			Lenteren & Woets,1980a	
	1983	8,000	4,000			Porcelli & D' Amore,1986	
(South Carol.)	1980			tom.	1,620	Lange & Bronson,1981	in low plastic tunnels

Table A - (cont.)

Country	year	area of greenhouses (ha) in the country	plastic houses	per crop	source	remarks
Mexico	1983	200			Porcelli & D' Amore,1986	
Costa Rica	1983	150			Porcelli & D' Amore,1986	50 ha of low plastic tunnels
Argentina	1983	500			Porcelli & D' Amore,1986	600 ha of low plastic tunnels
NORTH-EAST ASIA						
Japan	1956	696	571	veget. 588 flowers 108	Kishi,1974	
	1960	1,645	1,411	veget. 1,406 flowers 239	" "	
	1965	4,587	4,200	veget. 4,025 flowers 562	" "	
	1967	6,864	6,364	veget. 5,911 flowers 928	" "	
	1969	10,435	9,858	veget. 9,342 flower 1,093	" "	
	1971	14,533	13,857	cuc. 4,435 strawb 3,585 tom. 2,817 other veget. 2,212 flower 1,484	" "	
	1977	25,000		strawb 6,852 cuc. 6,218 tom. 4,377 water-melon 2,850 eggpl. 1,471 sweet-pepper 1,232	Yano,1981	
	1978	27,300		flow. 13,650 vege. 10,101 fruit 3,549	Lenteren & Woets,1980a	

Table A - (cont.)

Country	year	area of greenhouses (ha) in the country	plastic houses	per crop		source	remarks
Japan (cont.)	1982	30,000		strawb	7,630	Nakazawa,1983	
	1983	37,000	34,200			Porcelli & D' Amore,1986; Garnaud,1984	60,000 ha of low plastic tunnels
	1985	?	32,000			Hussey,1985	almost all area in plastic
South Korea	1972	?		cuc.	337	Dalrymple,1973	almost all area in plastic
				chinese cabb.	195		
				tom.	169		
				let.	169		
				melon	130		
				pepper	117		
				other veget.	180		
OCEANIA							
Austra-lia	1972	72				Dalrymple,1973	tomatoes, green peppers and cucumbers are the main crops
	1983	300	300			Porcelli & D' Amore,1986	50 ha of low plastic tunnels
New Zealand	1964	86				Dalrymple,1973	
	1968	100				" "	
	1972	116				" "	
	1984	140				Martin,1984; Nichols,1986	the main crops are tomatoes and cucumbers
WORLD							
	1971	12,150				Hussey & Bravenboer,1971	the authors considered only the glasshouse area

Table A - (cont.)

Country	year	area of greenhouses (ha) in the country	plastic houses	per crop	source	remarks
WORLD (cont.)						
	1980	80,000-90,000			Lenteren *et al.*, 1980b	
	1980	110,000	80,000		Garnaud, 1984	
	1983	152,545	113,388		Porcelli & D'Amore, 1986	129,150 ha of low plastic tunnels
	1983	130,000	100,000		Garnaud, 1984	
	1985	>150,000			Lenteren, 1985a	

APPENDIX I

1.2 - Table B - CHANGES IN BIOLOGICAL CONTROL BY COUNTRY, IN DIFFERENT CROPS

[Areas where biological control was applied are expressed as a percentage of total area of the crop]

Area (ha) and % of the crop where biocontrol is applied

country	year	Tomato								Cucumber								Sweet pepper				source	remarks
		P. persimilis		*B. formosa*		*A. aphidimyza*		*D. isaea*		*P. persimilis*		*B. formosa*		*A. aphidimyza*				*P. persimilis*		*A. aphidimyza*			
		ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%			ha	%	ha	%		
Belgium	1976	30	?																			Lenteren,1985b	
	1977	30	?																			" "	
	1981	60	5.6																			Lenteren,1985b; Pelerents,1986	
	1984	80	?																			Lenteren,1985b	
Bulgaria	1981	0.2	?			12	?															Woets & Lenteren, 1982	
	1982	1	0.14			5	0.71															Woets & Lenteren, 1983	
Czechos-lovakia	1981									1.5	1.5			1.5	1.5							Woets & Lenteren, 1982	
	1983									12	?			2.5	?							Woets & Lenteren, 1983	
Denmark	1976					45	45			28	70											Berendt,1980	
	1977					60	60			32	80											" "	
	1978					50	50			30	75											" "	
	1979	2	2.2			49	54.4			25	62.5			4	10			1	20			Lenteren & Woets, 1980b;Lenteren,1985b	
	1980	6	5			41	34.2			28	46.7			6	10							Woets & Lenteren, 1981;Lenteren,1985b	
	1981					46	40			46	83.6			4	7.2			3	30			Woets & Lenteren, 1982;Lenteren,1985b	
	1982					48	?			20	?											Lenteren,1985b	
	1984					50	?			23	?									2.5	?	" "	

Table B - (cont.)

Area (ha) and % of the crop where biocontrol is applied

country	year	Tomato								Cucumber								Sweet pepper				Green beans		source	remarks
		P. persimilis		*E. formosa*		*A. aphidimyza*		*D. isaea*		*P. persimilis*		*E. formosa*		*A. aphidimyza*		*P. persimilis*		*A. aphidimyza*		*P. persimilis*			
		ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%		
Denmark (cont.)	1986			60	77					28	87							7	3.5			Reitzel,1986	
Finland	1970									6	22											Berendt,1980	
	1974									31	70											" "	
	1975			t								t										" "	t-15 ha(7% Of total area of tomato and cucumber crops)
	1978			t						45	75	t										" "	t-50 ha(23% of total area of tomato and cucumber crops)
	1979	2	1.2	60	37.5	5	3.2			45	75	15	25	2	3.3							Lenteren & Woets, 1980b	
	1980	2	1.1	30	16.7	5	2.8			45	81.8	7	12.7	2	3.6							Woets & Lenteren, 1981	
	1981	2	1.1	20	11.4	5	2.9			45	84.9	3	5.7	2	3.8							Woets & Lenteren, 1982	
	1982	2	1.1	20	11.1	6	3.3			50	83.3	3	5	3	5							Woets & Lenteren, 1983	
France	1982			45	?					40	?											Woets & Lenteren, 1983	
	1983			110	?					75	?											Woets & Lenteren, 1984	
	1984			220	?			t		80	?											Lenteren,1985b; Minkenberg,1985	t- since 1982 until 1984 this parasitoid was used in 260 ha of greenhouse tomatoes
West-Germany	1976									3	?	1	?									Lenteren,1985b	
	1978t																					Hassan,1979	t-*Encarsia* and *Phytoseiulus* were applied on 5 ha of tomatoes and cucumbers

Table B - (cont.)

Area (ha) and % of the crop where biocontrol is applied

country	year	Tomato								Cucumber						Sweet pepper				Green beans		source	remarks
		P. persimilis		*E. formosa*		*A. aphidimyza*		*D. isaea*		*P. persimilis*		*E. formosa*		*A. aphidimyza*		*P. persimilis*		*A. aphidimyza*		*P. persimilis*			
		ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%		
West-Germany (cont.)	1979	0.7	0.3	6	2.6					2	?	0.5	?									Lenteren & Woets, 1980b	
	1980*																					Woets & Lenteren, 1981	*- *Encarsia* and *Phytoseiulus* were applied on 10 ha of tomato and cucumber crops
	1981			6	?					5	?	1	?							1	?	Woets & Lenteren, 1982	
Greece	1982*																					Kozirakis,1983	*- biological control applied on 16 ha of cucumber and 1 ha of tomato
	1986*																					Argyriou,1986	*- *Encarsia formosa* is applied on 17 ha and *Phytoseiulus persimilis* on 24 ha of tomatoes, cucumbers, greenbeans and melons
Hungary	1983			18	?											6	?					Woets & Lenteren, 1984	
Ireland	1976	2	?	2.5	?					0.5	?	0.5	?									Lenteren,1985b	
	1977	3	?	7	?					0.5	?	0.5	?			0.5	?					" "	
	1979	15	8.8	15	8.8					0.5	6.3	0.5	6.3			0.5	1.7					Lenteren & Woets, 1980b	
	1980	10	16	20	32					4	36.4	4	36.4			1	25					Woets & Lenteren, 1981	
	1982	20	?	20	?							2	?			1	?					Woets & Lenteren, 1983	
Nether-lands	1969									25	3											Woets *et al.*,1980	
	1970									200	25											" " " "	
	1971					4	0.16			75	10			4	0.53							" " " "	; Lenteren,1985b

Table B - (cont.)

Area (ha) and % of the crop where biocontrol is applied

country	year	Tomato								Cucumber								Sweet pepper						Gerkins		Melons		Ornamentals				source	remarks
		P. persimilis		*E. formosa*		*A. aphidimyza*		*D. sibirica*		*P. persimilis*		*E. formosa*		*A. aphidimyza*				*P. persimilis*		*A. aphidimyza*		*Amblyseius* sp.		*P. persimilis*		*P. persimilis*		*P. persimilis*		*E. formosa*		*D. sibirica*			
		ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%			ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%		
Netherlands (cont.)	1972	10	0.45	20	0.9					100	11.9	4	0.48																			Woets *et al.*, 1980;Lenteren, 1985b	
	1973	10	0.41	120	5					150	19	6	0.76					10	6.7													" " " "	
	1974	10	0.48	400	19.1					150	19	6	0.76					12	7.5													" " " "	
	1975	10	0.49	500	24.3					200	25.6	6	0.77					15	9.4													" " " "	
	1976	10	0.49	600	29.4					300	41.7	6	0.83					20	12.5													" " " "	
	1977	12	0.57	575	27.5					365	47.4	9	1.2					32	18.9					5	?	3	?					" " " "	
	1978			530	25					400	50							40	20					16	7							Woets & Lenteren, 1979	
	1979	14	0.7	590	28.8			3	0.1	395	54.9	10	1.4					40	22.2					28	11.7	2	?					Lenteren & Woets, 1980b	
	1980	14	0.7	580	28.9			32	1.6	430	61.4	11	1.6					37	18.5			1	0.5	30	12.5	2	4.4					Woets & Lenteren, 1981	
	1981	12	0.6	540	26.7			33	1.6	460	64.8	16	2.3					40	18.2			1	0.5	32	14.2	2	?	3*	?	1**	0.4	3*	?	Woets & Lenteren, 1982	*-2 ha on rose 1 ha on gerbera **- on gerbera
	1982	10	0.48	490	23.3					470	64.8	25	3.4					40	16													Woets & Lenteren, 1983	
	1983	10	0.5	520	26					480	69.6	35	5.1					55	21.6													Woets & Lenteren, 1984	
	1984			550	?					480	?	45	?					60	?			60	?									Lenteren, 1985b	
Norway	1978	7.5	?	2.7	?					11	?	0.2	?															0.4	?	0.1	?		Stenseth, 1979b	
	1979	7.5	?	2.7	?					11	?	0.2	?																				Lenteren, 1985b	

Table B - (cont.)

Area (ha) and % of the crop where biocontrol is applied

country	year	Tomato								Cucumber								Sweet pepper						Ornamentals				source	remarks
		P. persimilis		*E. formosa*		*A. aphidimyza*		*D. sibirica*		*P. persimilis*		*E. formosa*		*A. aphidimyza*				*P. persimilis*		*E. formosa*		*M. costalis*		*P. persimilis*		*E. formosa*			
		ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%			ha	%	ha	%	ha	%	ha	%	ha	%		
Norway (cont.)	1980	10	15.9	4	6.3																							Woets & Lenteren, 1981	
	1981	15	30	5	10																							Woets & Lenteren, 1982	
	1982	10	20	5	10					20	80	1	4															Woets & Lenteren, 1983	
	1983	20	40	10	20					22	88																	Woets & Lenteren, 1984	
Poland	1976											3	?															Lenteren,1985b	
	1977									6	?													1‡	?	1‡‡	?	" "	‡- on pot plants ‡‡- on roses
	1978	2	?	0.25	?					2.5	?	1.5	?											1.5‡	?			Pruszynski,1979	‡- pot plants = 0.5 ha rose = 1 ha
	1979	2	?							5	?													3‡	?			Lenteren & Woets, 1980b	‡- rose = 2 ha pot plants = 1 ha
	1980	2	0.2							2	?													1.5‡	?			Woets & Lenteren, 1981	‡- on rose
	1981	3.5	?							7	?	1.5	?											3‡	?			Woets & Lenteren, 1982	‡- on rose
	1984	10.5	?							20	?	6	?			3	?	1.5	?	3	?			6‡	?			Lenteren,1985b	‡- on rose
Romenia	1976	36	?									7	?			21.5	?											Lenteren,1985b	
	1977	135	?													24.5	?											" "	
Sweden	1975	27	30							14	35																	Berendt,1980	
	1976	41	45							30	75																	" "	
	1977	45	50							28	70																	" "	
	1978	41	45							28	70																	" "	

Table B - (cont.)

Area (ha) and % of the crop where biocontrol is applied

country	year	Tomato								Cucumber								Sweet pepper				Melons				source	remarks
		P. persimilis		*E. formosa*		*A. aphidimyza*		*D. sibirica*		*P. persimilis*		*E. formosa*		*D. sibirica*		*P. persimilis*		*A. matricarie*		*P. persimilis*					
		ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%				
Sweden (cont.)	1979			40	44.4							28	70											Lenteren & Woets, 1980b	
	1980			25	27.8					30	60	2	4							5	71.4			Woets & Lenteren, 1981	
	1981			30	33.3			1	1.1	30	60	3	6							5	71.4			Woets & Lenteren, 1982	
	1982			25	39					30	51.7			1	1.7					3	75			Woets & Lenteren, 1983	
	1983			30	42.9					40	66.7													Woets & Lenteren, 1984	
	1984			30	?					45	?													Lenteren,1985b	
Switzerland	1979*																							Freuler & Stadler,1980	*- 12 ha of tomato and cucumber (12% of area of both crops)
	1980			10	10.9					5	14.7	1	2.9											Woets & Lenteren, 1981	
	1981	10	9.5	10	9.5					4	10.3	4	10.3											Woets & Lenteren, 1982	
(England -Wales)	1973*																							Parr,1973	*- 120 ha treated with *P. persimilis* and *E. formosa*
	1975	11	2*	22	3*					15	7*	20	10*											Gould,1977; 1984	*- % values related with heated crop area,only
	1976	42	8*	86	16*					89	45*	54	27*											" " "	*- % values related with heated crop area,only
United Kingdom	1977	79	15*	146	27*					94	47*	87	43*			1.2	?			0.4	?			Gould,1980	*- % values related with heated crop area,only
	1978	108	20*	168	31*					164	72*	81	36*											" "	*- % values related with heated crop area,only

Table B - (cont.)

Area (ha) and % of the crop where biocontrol is applied

country	year	Tomato								Cucumber								Sweet pepper				Melons		Ornamentals								source	remarks
		P. persimilis		*E. formosa*		*A. aleyrodis*		*V. lecanii*		*P. persimilis*		*E. formosa*		*V. lecanii*				*P. persimilis*		*B. formosa*		*P. persimilis*		*P. persimilis*		*E. formosa*		*V. lecanii*		*D. sibirica*			
		ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%			ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%		
(England -Wales) (cont.)	1979	143	26	223	40.5					145	64.4	91	40.4																			Lenteren & Woets, 1980b	
	1980	73	13.3	216	39.3					161	74.5	99	45.8															1‡	0.5			Woets & Lenteren, 1981	‡-on chrysanthemum
	1981	75	13.6	210	38.2					170	77.3	100	45.5															2.4‡	?			Woets & Lenteren, 1982	‡- on chrysanthemum
	1983	71	16.9	144	34.3					157	68.3	103	44.8	5.6	2.4									9‡	?			6.5‡	?	2.6‡	?	Woets & Lenteren, 1984	‡- on chrysanthemum
(Scotland)	1979‡	4	17.4	3	13																											Lenteren & Woets, 1980b	‡- *B. thuringiensis* applied on 1.6 ha
	1980	2.5	12.5	0.1	0.5																											Woets & Lenteren, 1981	
	1981	2.7	13.5	0.4	2																											Woets & Lenteren, 1982	
USSR	1979			42	?			88	?																							Lenteren & Woets, 1980b	
	1981																	14	23.3			1	1.7									Woets & Lenteren, 1982	
	1982‡																															Popov, 1983	‡- 3828 ha treted with *P. persimilis*, *E. formosa*, *A. aphidimyza* and *C. carnea*
Israel	1984																							60	?							Lenteren, 1985b	
Canada	1979			0.9	9																											Lenteren & Woets, 1980b	
	1980			4	20					8	72.7																					Woets & Lenteren, 1981	
	1981			8	36.4					26	74.3	16	45.7																			Woets & Lenteren, 1982	

Table B - (cont.)

Area (ha) and % of the crop where biocontrol is applied

country	year	Tomato								Cucumber						Sweet pepper				Strawberries		Ornamentals				source	remarks
		P. persimilis		E. formosa		A. aleyrodis		V. lecanii		P. persimilis		E. formosa		V. lecanii		P. persimilis		E. formosa		P. persimilis		P. persimilis		E. formosa			
		ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%		
Japan	1979																			1.1	?					Lenteren & Woets, 1980b	
	1980																			15	0.22					Woets & Lenteren, 1981	
	1981																			3	0.034					Woets & Lenteren, 1982	
	1982																			1	0.14					Woets & Lenteren, 1983	
Australia	1983									6	20															Woets & Lenteren, 1984	

APPENDIX II

2.1 - PORTUGUESE VERSION OF THE SURVEY QUESTIONNAIRE CARRIED OUT IN PORTUGAL

UNIVERSIDADE DE LONDRES / UNIVERSIDADE TÉCNICA DE LISBOA
IMPERIAL COLLEGE / INSTITUTO SUPERIOR DE AGRONOMIA

INQUÉRITO SOBRE PROBLEMAS FITOSSANITÁRIOS
EM CULTURAS PROTEGIDAS
(Hortícolas)

Este inquérito é ***CONFIDENCIAL***
e destina-se unicamente ao estudo
de questões de natureza técnica.

Inquérito no. _____ Freguesia_____
Data ___/___/_____ Concelho _____

I- INFORMAÇÃO GERAL

1- Há quantos anos se dedica à produção de culturas em estufa, nesta exploração ?_____

2- Qual é a area de estufas de que dispõe (ha)?

≤ 1	>1-5	>5-10	>10-25	>25

3- Tendo em conta as principais culturas hortícolas produzidas em estufa:

CULTURAS	a) quais são as que está a produzir ou prevê vir a cultivar este ano (Ago.-Jul.) e areas ocupadas por cada uma?		b) nos últimos três anos quantas vezes produziu esta cultura?	c) qual foi a produção que obteve no ano passado?	d) quais as variedades que está a utilizar ou prevê vir a usar?
TOMATE	_____	_____ m2/ha	_____	_____(kg/m2)(t/ha)	_____
MELÃO	_____	_____ m2/ha	_____	_____(kg/m2)(t/ha)	_____
FEIJÃO VERDE	_____	_____ m2/ha	_____	_____(kg/m2)(t/ha)	_____
ALFACE	_____	_____ m2/ha	_____	_____(kg/m2)(t/ha)	_____
PIMENTO	_____	_____ m2/ha	_____	_____(kg/m2)(t/ha)	_____
PEPINO	_____	_____ m2/ha	_____	_____(kg/m2)(t/ha)	_____
BERINGELA	_____	_____ m2/ha	_____	_____(kg/m2)(t/ha)	_____
MELANCIA	_____	_____ m2/ha	_____	_____(kg/m2)(t/ha)	_____
MORANGOS	_____	_____ m2/ha	_____	_____(kg/m2)(t/ha)	_____
OUTRAS(especificar)					
_____	_____	_____ m2/ha	_____	_____(kg/m2)(t/ha)	_____
_____	_____	_____ m2/ha	_____	_____(kg/m2)(t/ha)	_____
_____	_____	_____ m2/ha	_____	_____(kg/m2)(t/ha)	_____

Inquérito no._____

4- Qual é a sequência cultural que utiliza? _____
_____; qual a duração desta?_____

5- Nos próximos 3-4 anos tenciona (AUMENTAR / DIMINUIR / MANTER) o numero das diversas culturas que actualmente produz? porquê e quais culturas?_____
_____

6- Produz alguma destas culturas ao ar livre, na mesma exploração? (SIM/NÃO); (se Sim, quais as culturas e em que area?)

	CULTURAS	AREA
I	_____	_____ m2/ha
II	_____	_____ m2/ha
III	_____	_____ m2/ha
IV	_____	_____ m2/ha
V	_____	_____ m2/ha

7- Quais são as principais culturas nas explorações agrícolas vizinhas?

CULTURAS EM ESTUFA _____	CULTURAS AO AR LIVRE _____	FLORESTAS E MATO _____
TOMATE _____	VINHA _____	PINHAL _____
MELÃO _____	POMARES _____	EUCALIPTAL _____
FEIJÃO VERDE _____	CEREAIS _____	OUTRAS (especificar)
ALFACE _____	BATATA _____	_____
PIMENTO _____	FAVA _____	_____
PEPINO _____	TOMATE _____	_____
MORANGOS _____	MELÃO _____	_____
ORNAMENTAIS _____	MORANGOS _____	_____
_____	COUVES _____	
_____	CENOURA _____	
_____	ALFACE _____	
_____	ERVILHA _____	
OUTRAS (especificar)	OUTRAS (especificar)	
_____	_____	
_____	_____	

8- Nos últimos 3-4 anos (MANTEVE / ALTEROU / AUMENTOU / DIMINUIU) , qualitativa ou quantitativamente, algum aspecto técnico no que respeita a:
(caso se tenha verificado alguma mudança, perguntar qual e porquê)

ESTRUTURA DA ESTUFA E TIPO DE PLÁSTICO_____
_____
_____

...(cont.)...

Inquérito no._____

8- (cont.)

ESTRUMAÇÃO_____

_____

ADUBAÇÃO_____

_____

REGA_____

_____

AREJAMENTO_____

_____

MANEJO DAS PLANTAS (poda, tutoragem, desfolha, colheita, limpeza dos restos da cultura,...)_____

_____

_____

_____

OUTROS (especificar)

_____

_____

_____

_____

9- Qual é o tipo de solo que predomina na sua exploração?_____

_____

II- PROBLEMAS FITOSSANITÁRIOS E PROTECÇÃO DAS CULTURAS

10-Quais são os problemas fitossanitários que costumam surgir nas suas culturas e em que período do ano os seus ataques são mais preocupantes? (O- Outono; I- Inverno; P- Primavera/Verão)

(A lista abaixo indica alguns dos inimigos das culturas hortícolas em estufa susceptiveis de ocorrerem no país)

TOMATE:a)mosca branca_____ b)aranhiços_____ c)afídeos_____ d)lagartas_____ e)larvas mineiras____ f)podridão cinzenta_____ g)míldio_____ h)oídio_____ i)alternariose_____ j)septoriose_____ l)encortiçamento das raízes_____ m)murchidões_____ n)nemátodos_____ o)bactérias_____ p)viroses_____ q)outros (especificar) q1)_____ q2)_____ q3)_____ q4)_____

MELÃO:a)aranhiços_____ b)afídeos_____ c)mosca branca_____ d)tripes_____ e)oídio_____ f)podridão radicular_____ g)podridão cinzenta_____ h)míldio_____ i)nemátodos_____ j)outros(especificar)j1)_____ j2)_____ j3)_____ j4)_____

...(cont.)...

Inquérito no._____

10- (cont.)

FEIJÃO VERDE: a)afídeos_____ b)aranhiços_____ c)mosca branca_____
d)podridão cinzenta_____ e)antracnose_____
f)ferrugem_____ g)oídio_____ h)bactérias_____
i)viroses_____ j)nemátodos_____ l)outros(especificar) l1)_____ l2)_____
l3)_____ l4)_____

ALFACE: a)afídeos_____ b)*Sclerotinia*/podridão cinzenta_____
c)míldio_____ d)nemátodos_____ e)outros (especificar) e1)_____ e2)_____
e3)_____ e4)_____

PIMENTO: a)afídeos_____ b)mosca branca_____ c)aranhiços_____
d)míldio_____ e)podridão cinzenta_____
f)viroses_____ g)outros(especificar)g1)_____
g2)_____ g3)_____ g4)_____

PEPINO: a)afídeos_____ b)mosca branca_____ c)aranhiços_____
d)oídio_____ e)podridão cinzenta_____
f)míldio_____ g)outros(especificar)g1)_____
g2)_____ g3)_____ g4)_____

MORANGOS: a)aranhiços_____ b)afídeos_____ c)mosca branca_____
d)podridão cinzenta_____ e)oídio_____
f)bactérias_____ g)viroses_____ h)outros (especificar) h1)_____ h2)_____
h3)_____ h4)_____

11- Tendo em conta as infestantes e os seus efeitos nas culturas:

	A)	B)
a)quais são as culturas mais afectadas pelas infestantes?		
b)quais são as infestantes que causam mais problemas ou que são mais frequentes/abundantes?		
c)como e quando controla as infestantes?		

...(cont.)...

Inquérito no._____

11- (cont.)

CULTURAS	A)_____	B)_____
d)já experimentou algum outro método alternativo? (se sim, especificar)		
e)se aplicar herbicidas, quais utiliza e quando os aplica?		

12- No caso de aplicar herbicidas, acha que tem que aplicar uma dose maior do que a recomendada pelos fabricantes ou consegue obter bons resultados com uma dose menor do que a recomendada?____

13- Costuma combater as infestantes existentes à volta da estufa? (SIM/NÃO); (se Sim, porquê e que método utiliza no seu combate?)

14- Considerando agora cada uma das principais culturas que costuma produzir em estufa:

CULTURAS	A)_____		B)_____	
a)quais são os dois problemas fitossanitários mais graves nesta cultura?	1)	2)	1)	2)
b)quando foi que este inimigo da cultura (i.c.) lhe começou a causar problemas?				

...(cont.)...

Inquérito no._____

14- (cont.)

CULTURAS	A)_____		B)_____	
PROBLEMAS MAIS GRAVES	1)_____	2)_____	1)_____	2)_____
c)este i.c. causa-lhe problemas todos os anos? (se Não, quantos anos em cada 5-10-desde que começou a produzir)				
d)qual foi o método de controlo que utilizou no ano passado?				
(Se utilizou luta química) d1)que pesticidas aplicou?				
d2)quando aplicou os pesticidas? (em que mês iniciou as aplicações de pesticidas e quando acabou as pulverizações?)				
d3) quantas vezes pulverizou? (se utilizou um calendário de tratamentos, qual era o intervalo entre duas pulverizações?)				
d4)acha que tem necessidade de aumentar a conc./dose recomendada pelos fabricantes, ou consegue obter bons resultados com uma quantidade menor de produto?				
d5)nos últimos 3-4 anos alterou os pesticidas que aplica? porquê?				

...(cont.)...

Inquérito no._____

14- (cont.)

CULTURAS	A)_____		B)_____	
PROBLEMAS MAIS GRAVES	1)_____	2)_____	1)_____	2)_____
e)tenciona aplicar, no presente ano, exactamente o mesmo método de controlo se tiver o mesmo problema?porquê?				
f)para alem dos pesticidas que utiliza, já usou algum outro que pudesse aplicar no combate a este problema? (ex: pesticidas usados pelos vizinhos) (se Sim, quais?)				
g) qual é o prejuízo que pensa que este i.c. pode causar na cultura, depois de aplicar o método de controlo que utiliza?	1) %	2) %	1) %	2) %
h) qual é o prejuízo que pensa que este i.c. poderia causar na cultura se o não controlasse?	1) %	2) %	1) %	2) %
i) qual é a % de plantas que geralmente aparecem atacadas?				
j)(no caso dos principais i.c. não englobarem insectos/ácaros) qual é a praga que causa mais problemas?				

Inquérito no._____

15- Como costuma aplicar os pesticidas?

-Pulverização _____
-Distribuição de grânulos_____
-Na água de rega_____
-Incorporados no solo_____ c/ água_____
c/ mobilização_____

16- De entre os problemas seguintes ligados com a protecção das culturas, quais lhe parecem mais importantes?

- Custos elevados dos produtos e da sua aplicação
- Ocorrência de prejuízos elevados
- Preocupação causada pelos prejuízos que podem vir a ocorrer
- Toxicidade dos pesticidas para os trabalhadores
- Necessidade de dedicar à protecção das culturas muito tempo e bastante atenção

17- (Se na pergunta 10 tiver sido detectado algum problema fitossanitário no solo e se na pergunta 14 nenhum dos indicados como mais graves for um problema de solo)

Como resolve os problemas fitossanitários que lhe surgem no solo?
_____

(se aplicar pesticidas, quais os produtos, quando os aplica e quantas aplicações efectua?) _____
_____
_____

(acha que a conc./dose recomendada pelos fabricantes dá bons resultados?)_____
_____

18- Costuma produzir as plantas para as suas culturas em viveiro na sua exploração? (SIM/NÃO)

a) Se NÃO - Quando adquire as plantas estas transportam para o interior da sua estufa algumas pragas ou doenças? (SIM/NÃO);(se Sim, plantas de que culturas e quais os inimigos da cultura?)
I-_____
II-_____
III-_____
IV-_____
V-_____

...(cont.)...

Inquérito no._____

18- (cont.)

b) Se SIM - As plantas sofrem no viveiro o ataque de algum dos inimigos da cultura referidos na pergunta 10 ? (SIM/NÃO);(se Sim, quais os problemas que se verificam por cultura?)

TOMATE _____
MELÃO _____
FEIJÃO VERDE (caso não seja de sementeira directa)_
_____
ALFACE _____
PIMENTO _____
PEPINO _____
MORANGOS _____

Como os controla ?_____
_____

19- Como detecta, normalmente, os problemas fitossanitários nas suas culturas?

((_____ a) observa as suas culturas para detectar a existência de pragas, doenças ou infestantes ou qualquer outro problema? (SIM/NÃO); se Sim, com que frequência o faz?_____

_____ b) observa a existência de problemas fitossanitários no decorrer das diversas operações culturais efectuadas no interior da estufa?

_____ c) ...não dedica especial atenção aos problemas fitossanitários até ver plantas atacadas.))

20- Pensa que se dedicasse mais tempo à observação das plantas na estufa , obteria benefícios adicionais? (SIM/NÃO). Porquê?_____
_____;
pensa que seria possível aumentar o tempo que dedica à inspecção das suas culturas? (SIM/NÃO). Porquê?_____
_____

21- Acha que durante os últimos anos os problemas fitossanitários das culturas em estufa têm:

a) aumentado de importância; b) mantido a mesma importância; c) diminuido de importância.

CULTURAS	IMPORTÂNCIA	PORQUE AFIRMA TAL
TOMATE	_____	_____
MELÃO	_____	_____
FEIJÃO VERDE	_____	_____
ALFACE	_____	_____
PIMENTO	_____	_____
PEPINO	_____	_____
MORANGO	_____	_____

Inquérito no._____

III- DIFICULDADES SENTIDAS NA PROTECÇÃO DAS CULTURAS

22- Acha que dispõe de informação suficiente sobre os problemas fitossanitários das suas culturas e dos pesticidas que aplica? (SIM/NÃO).

(se Não, que tipo de informação gostaria de obter?)_____
_____
_____
quem acha que lhe deveria fornecer essa informação?_____
_____
estaria disposto a pagar essa informação?_____
_____
_____

23- Onde obtem, normalmente, a informação técnica sobre problemas fitossanitários, pesticidas e sobre outros métodos de controlo?

FONTES	PROBLEMAS FITOSSANITÁRIOS	PESTICIDAS	OUTROS MÉTODOS DE CONTROLO
VENDEDORES DE PESTICIDAS			
EMPRESAS DE PESTICIDAS			
MINISTÉRIO DA AGRICULTURA			
OUTROS PRODUTORES, AMIGOS			
COOPERATIVAS			
JORNAIS, RÁDIO, TELEVISÃO			
REVISTAS DE NATUREZA TÉCNICA			
FOLHETOS E MANUAIS DAS EMPRESAS DE PESTICIDAS			
REUNIÕES DE DIVULGAÇÃO DAS EMP. PESTICIDAS			
OUTRAS (especificar)			
_____			
_____			
_____			

24- De uma maneira geral, acha que a informação que consegue obter é (MUITO ÚTIL / POUCO ÚTIL / INUTIL) na melhoria da protecção das suas culturas.

25- Quando lhe aparece um novo problema fitossanitário onde obtem informações sobre o que deve fazer para o combater?_____
_____
_____

26- Teve recentemente alguma dificuldade em controlar algum inimigo das culturas que costumasse controlar facilmente? (SIM/ /NÃO). (Se Sim, especificar)_____
_____

Inquérito no._____

27- Existe algum problema fitossanitário nas suas culturas de estufa que nunca tenha conseguido controlar satisfatoriamente?___
_____
_____

28- Está satisfeito com a eficácia dos pesticidas que aplica? (SIM/NÃO); Porquê?_____
_____;

Quando comparados com outros custos de produção (estrume, adubos, sementes), acha os pesticidas :

MUITO CAROS ¦ CAROS ¦ PREÇO RAZOÁVEL ¦ BARATOS

29- Está satisfeito com a eficácia do material de aplicação que utiliza? (SIM/NÃO); porquê?_____
_____;

considera que os custos da aplicação dos pesticidas são:

EXTREMAMENTE ELEVADOS ¦ ELEVADOS ¦ RAZOAVEIS ¦ BAIXOS

30- Em que medida a época da colheita lhe afecta a aplicação de pesticidas?_____
_____
_____

IV- FUTURO

31- Pensa que os prejuízos causados pelos actuais inimigos das culturas irão (AUMENTAR / MANTER-SE / DIMINUIR / NÃO SABE) nos próximos 5 anos? Porquê?_____
_____
_____

32- Acha que o número de inimigos das culturas que irão afectar as suas culturas nos próximos 5 anos irá (AUMENTAR / MANTER-SE / / DIMINUIR / NÃO SABE)? Porquê?_____
_____
_____

33- Prevê vir a ter algumas dificuldades futuras para controlar problemas fitossanitários que actualmente controla de forma satisfatória? (SIM/NÃO/NÃO SABE). (Se Sim, quais e porquê?)_____
_____
_____

Inquérito no._____

34- Em seu entender, que melhorias o ajudariam mais a aperfeiçoar a protecção das suas culturas no futuro?

_____ PESTICIDAS MAIS EFICAZES
_____ PESTICIDAS MAIS SEGUROS
_____ PESTICIDAS MAIS BARATOS
_____ MELHOR MATERIAL DE APLICAÇÃO
_____ MAIS INFORMAÇÃO SOBRE OS PESTICIDAS E O MATERIAL DE APLICAÇÃO
_____ CULTIVARES RESISTENTES
_____ MÉTODOS DE CONTROLO NÃO QUÍMICOS
_____ SERVIÇO DE AVISOS EFICAZ
_____ MAIS INFORMAÇÃO SOBRE OS INIMIGOS DAS CULTURAS E OS PREJUÍZOS QUE CAUSAM
_____ OUTROS_____
_____
_____ NENHUMA MUDANÇA, CONTENTE COM SITUAÇÃO ACTUAL

V- CARACTERIZAÇÃO DOS PRODUTORES

35- Em que altura do ano compra os pesticidas?_____
_____

36- Considera que a informação existente no rótulo das embalagens de pesticidas é:_____

a)DESNECESSÁRIA b)EXCESSIVA
c)ÚTIL d)ESSENCIAL

37- Algumas pessoas são de opinião de que é possível combater as pragas com outros insectos benéficos. Qual é a sua opinião a este respeito?_____
_____
_____
_____

38- Algumas pessoas são de opinião de que é possível combater os problemas fitossanitários do solo (doenças do solo, nemátodos, infestantes) pelo recurso à "SOLARIZAÇÃO" (aquecimento do solo, coberto por uma fina película de plástico, por acção dos raios solares). Qual é a sua opinião a este respeito?_____
_____
_____
_____

39- Utiliza cultivares resistentes como uma forma de controlar os problemas fitossanitários? (SIM/NÃO). Porquê?_____
_____
_____

40- Faz algum seguro de colheita para as suas culturas em estufa? _____; Sabe se os seus vizinhos costumam fazer seguro de colheita?_____

Inquérito no._____

41- Quando utiliza um pesticida fá-lo porque assim aumenta sempre a produção ou porque a sua aplicação evita às vezes a ocorrência de prejuízos elevados?_____

_____

_____

42- A que grupo etário pertence?

≤20 21-30 31-40 41-50 51-60 >60

43- Quais são as suas habilitações?_____

_____

44- Relativamente aos problemas fitossanitários e aos métodos de protecção das culturas, existe algum assunto que considere importante e que eu não tenha abordado?_____

_____

_____

MUITO OBRIGADO
pela sua *DISPONIBILIDADE*
e *PARTICIPAÇÃO*

NOTAS

APPENDIX II

2.2 - ENGLISH VERSION OF THE SURVEY QUESTIONNAIRE CARRIED OUT IN PORTUGAL

UNIVERSITY OF LONDON / TECHNICAL UNIVERSITY OF LISBON
IMPERIAL COLLEGE / AGRICULTURAL INSTITUTE

SURVEY OF PEST PROBLEMS IN PROTECTED CROPS
(Vegetables)

This is a *CONFIDENTIAL* survey
to study technical problems.

Survey no. _____ Parish_____
Date _____/___/_____ District_____

I- GENERAL INFORMATION

1- For how long have you been producing protected crops on this farm?_____

2- What is your greenhouse area (ha)?

≤1	>1-5	>5-10	>10-25	>25

3- With respect to the major vegetable crops in the greenhouse:

CROPS	a)which are you growing or planning to grow this year (Aug-Jul) and what areas?		b)in the last three years,how many times did you grow this crop ?	c)what yield did you obtain last year ?	d)which varieties are you growing or planning to grow this year ?
TOMATO	___	_____ m2/ha	_____	_____(kg/m2)(t/ha)	_____
MELON	___	_____ m2/ha	_____	_____(kg/m2)(t/ha)	_____
GREEN BEANS	___	_____ m2/ha	_____	_____(kg/m2)(t/ha)	_____
LETTUCE	___	_____ m2/ha	_____	_____(kg/m2)(t/ha)	_____
SWEET PEPPER	___	_____ m2/ha	_____	_____(kg/m2)(t/ha)	_____
CUCUMBER	___	_____ m2/ha	_____	_____(kg/m2)(t/ha)	_____
AUBERGINE	___	_____ m2/ha	_____	_____(kg/m2)(t/ha)	_____
WATER-MELON	___	_____ m2/ha	_____	_____(kg/m2)(t/ha)	_____
STRAWBERRIES	___	_____ m2/ha	_____	_____(kg/m2)(t/ha)	_____
OTHERS (specify)					
_____	___	_____ m2/ha	_____	_____(kg/m2)(t/ha)	_____
_____	___	_____ m2/ha	_____	_____(kg/m2)(t/ha)	_____
_____	___	_____ m2/ha	_____	_____(kg/m2)(t/ha)	_____

Survey no._____

4- What is your cropping sequence ?_____
_____; What is its duration ?_____
_____

5- In the next 3- 4 years do you plan to (INCREASE / DECREASE / / MAINTAIN) the number of different crops you grow? Why and which crops ?_____
_____

6- Do you grow any of these crops in the open, on the same farm? (YES/NO); (if YES: which crops and on which area?)

	CROPS	AREA
I	_____	_____ m2/ha
II	_____	_____ m2/ha
III	_____	_____ m2/ha
IV	_____	_____ m2/ha
V	_____	_____ m2/ha

7- What are the main crops in the neighbouring farms?

GREENHOUSES	FIELD CROPS	FORESTRY AND WOODLAND
TOMATO	VINEYARDS	PINES
MELON	ORCHARDS	EUCALYPTUS
GREEN BEANS	CEREALS	OTHERS (specify)
LETTUCE	POTATOES	
SWEET PEPPER	BROAD BEANS	
CUCUMBER	TOMATO	
STRAWBERRIES	MELON	
ORNAMENTALS	STRAWBERRIES	
	CABBAGES	
	CARROTS	
	LETTUCE	
	PEAS	
OTHERS (specify)	OTHERS (specify)	

8- In the last 3-4 years did you (MAINTAIN / CHANGE / INCREASE / / DECREASE) your technical inputs in relation to:

(if some change has occurred ask which and why)

GREENHOUSE STRUCTURE & PLASTIC TYPE_____
_____

...(cont.)...

Survey no._____

8- (cont.)

MANURING_____

FERTILISATION_____

IRRIGATION_____

VENTILATION_____

CROP MANAGEMENT (pruning, training, deleafing, harvesting, treatment of crop residues,...)_____

OTHERS (specify)

9- What is the predominant soil type on your farm?_____

II- PEST PROBLEMS & CROP PROTECTION

10- Which pest problems do you usually find in your crops and when do they cause most trouble? (A- autumn; W- winter; S- spring/summer)

(The list below shows some greenhouse vegetable pests that might occur in the country)

TOMATO: a)whitefly_____ b)spider mites_____ c)aphids_____
d)caterpillars_____ e)leafminers_____ f)grey mould_____
g)late blight_____ h)powdery mildew_____ i)early blight_____
j)septoria leaf spot_____ l)corky root rot_____
m)wilt diseases_____ n)nematodes_____ o)bacteria_____
p)viruses_____ q)others (specify) q1)_____
q2)_____ q3)_____ q4)_____

MELON: a)spider mites_____ b)aphids_____ c)whitefly_____
d)thrips_____ e)powdery mildew_____ f)root rot_____
g)grey mould_____ h)downy mildew_____ i)nematodes_____
j)others (specify) j1)_____ j2)_____
j3)_____ j4)_____

...(cont.)...

Survey no._____

10- (cont.)

GREEN BEANS: a)aphids_____ b)spider mites_____ c)whitefly_____
d)grey mould____e)anthracnose_____ f)rust _____
g)powdery mildew_____ h) bacteria_____
i) viruses_____ j)nematodes_____ k)others
(specify) k1)_____ k2)_____
k3)_____ k4)_____

LETTUCE: a)aphids_____ b)*Sclerotinia*/grey mould_____
c)downy mildew_____ d) nematodes_____ e)others
(specify) e1)_____
e2)_____ e3)_____
e4)_____

SWEET PEPPER: a)aphids_____ b)whitefly_____ c)spider
mites_____ d)stem rot_____ e)grey mould_____
f)viruses_____ g)others (specify)g1)_____
g2)_____ g3)_____ g4)_____

CUCUMBER: a)aphids_____ b)whitefly_____ c)spider
mites _____ d)powdery mildew_____ e)grey mould_____
f)downy mildew_____ g)others (specify)
g1)_____ g2)_____ g3)_____
g4)_____

STRAWBERRIES: a)spider mites_____ b)aphids_____ c)whitefly_____
d)grey mould_____ e)powdery mildew_____
f)bacteria_____ g)viruses_____ h)others(specify
h1)_____ h2)_____ h3)_____
h4)_____

11- In relation to weeds and their effect on the crops:

a) Which are the crops most affected by weeds?	A)_____	B)_____
b) Which weeds either cause the most problems or are the most frequent/abundant?	_____ _____ _____ _____ _____ _____	_____ _____ _____ _____ _____ _____
c)How and when do you control weeds?	_____ _____ _____ _____	_____ _____ _____ _____

...(cont.)...

Survey no._____

11- (cont.)

CROPS	A)_____	B)_____
d) Have you ever tried any alternative method ? (if yes, specify)		
e) If you apply herbicides, which ones and when are they applied ?		

12- If you apply herbicides do you find that you have to use more than the manufacturers recommend, or do you find you can get away with less?_____

13- Do you usually control weeds outdoors, around the greenhouses ? (YES/NO) (if YES: why and which control method do you use ?)_____

14- In relation to the main crops you usually grow in your greenhouses:

CROPS	A)_____		B)_____	
a) Which are the worst two pest problems in this crop?	1)	2)	1)	2)
b) When did the pest begin to cause problems to your crop?				

...(cont.)...

Survey no._____

14- (cont.)

CROPS	A)_____		B)_____	
WORST PEST PROBLEMS	1)_____	2)_____	1)_____	2)_____
c)Does it cause problems every year? (if not, how many years in each 5 / 10 / / since you began growing)				
d) What control method did you use last year?				
(If chemical control) d1)What pesticides did you apply ?				
d2)When did you apply the chemicals? (in which month did you begin applying chemicals and when did you finish spraying?)				
d3)How often did you spray?(if on a calendar spraying scheme, what was the interval between sprays ?				
d4)Do you find you need to increase the conc./dose recommended by the manufacturers, or do you find you can obtain good results with less?				
d5) In the last 3-4 years did you change chemicals at all? why?				

...(cont.)...

Survey no._____

14- (cont.)

CROPS	A)_____		B)_____	
WORST PEST PROBLEMS	1)_____	2)_____	1)_____	2)_____
e)Are you planning to use the same control method this year if you have the same problem ? why?				
f) Apart from the chemicals you use,have you ever applied any other chemical that you could use against this problem? (ex: chemicals used by neighbours) (if Yes, which ?)				
g) How much loss do you think this pest causes to your crop after applying the control method you use?	1) %	2) %	1) %	2) %
h) How much loss do you think this pest could cause to your crop if you hadn't controlled it ?	1) %	2) %	1) %	2) %
i) What is the % of plants that usually become affected ?				
j) (If the worst two pest problems don't include an insect/mite ask:) What is the worst insect/mite pest problem ?				

Survey no._____

15- How do you apply the pesticides ?

-Spraying_____
-granule spreading_____
-in the irrigation water_____
-incorporated into the soil_____with water_____
mechanically_____

16- Of the following problems related to crop protection, which ones would you consider the most important?

- High costs of pesticides and application methods
- Occurrence of high losses
- Concern caused by potential losses
- Pesticide toxicity to field workers
- Large amount of time and attention needed for good crop protection

17- [If any soil problem has been mentioned in question 10, but without being covered in question 14 (worst problems), ask:]

How do you solve pest problems in the soil?_____

(If chemicals, what chemicals, when are they applied and how often ?)

_____
_____
_____

(Do you find the conc./dose recommended by the manufacturers gives good results?) _____
_____

18- Do you produce your own seedlings in your nursery? (YES/NO)

a) If NO - When you buy seedlings, do these carry any pest propagules on them to your greenhouse? (Yes/No); (if Yes, which crop seedlings and pests?)

I-_____
II-_____
III-_____
IV-_____
V-_____

...(cont.)...

Survey no._____

18- (cont.)

b) IF YES - Do you have in the nursery any of the pest problems to which you referred in question n.o 10 ? (YES/NO); (if Yes, specify the pest problems by crop)

TOMATO _____
MELON _____
GREEN BEANS (if not direct-sown)_____
_____
LETTUCE _____
SWEET PEPPER _____
CUCUMBER _____
STRAWBERRIES_____

How do you control them?_____
_____
_____

19- How do you usually detect your pest problems?

((_____ a) do you inspect your crops to check for insects/diseases/weeds or other pest problems? (YES/NO); if YES, on average how often? _____
_____

_____ b) do you inspect the plants for pest problems when you are doing other technical work in the greenhouse?

_____ c) ... you do not pay attention to pest problems until you see several plants affected.))

20- Do you think that if you spent more time inspecting the plants, you would gain more benefits? (YES/NO). Why or why not?__
_____;
Would it be possible for you to increase the time you spend inspecting your crops? (YES/NO). Why or why not?_____
_____.

21- Do you think that during the last few years the pest problems on your crops have been:

a) increasing in importance; b) staying the same;
c) decreasing in importance.

CROPS	IMPORTANCE	WHY DO YOU SAY THAT
TOMATO	_____	_____
MELON	_____	_____
GREEN BEANS	_____	_____
LETTUCE	_____	_____
SWEET PEPPER	_____	_____
CUCUMBER	_____	_____
STRAWBERRIES	_____	_____

Survey no._____

III- DIFFICULTIES IN CROP PROTECTION

22- Do you think you have access to sufficient information about your pest problems and the pesticides you use? (YES/NO)

(If NO, what type of information would you like to obtain?)

_____

_____

Who do you think should provide you with that information?_

_____

Would you be willing to pay for it?_____

_____

23- Where do you usually obtain technical information about pest problems, pesticides and other methods of control?

SOURCES	PEST PROBLEMS	PESTICIDES	OTHER CONTROL METHODS
PESTICIDE DEALERS			
PESTICIDE COMPANIES			
MINISTRY OF AGRICULTURE			
OTHER GROWERS, FRIENDS			
COOPERATIVES			
NEWSPAPERS , RADIO, TV			
TECHNICAL MAGAZINES			
PESTIC. COMPANIES LITERATURE			
PESTIC. COMPANIES MEETINGS			
OTHERS (specify)			
_____			
_____			
_____			

24- In a general way, do you think the information you are able to obtain is (VERY USEFUL / SOMEWHAT USEFUL / NOT USEFUL) in improving your pest control methods.

25- When a new pest problem appears, where do you obtain information on how to control it? _____

_____

_____

26- Have you recently had any difficulty controlling any pest problem which you had previously been able to control easily? (YES/NO) (If Yes, specify)_____

_____

_____

Survey no._____

27- Do you have any pest problems for which you have never had a satisfactory control method?_____

_____

_____

28- Are you satisfied with the efficacy of the pesticides you apply? (YES/NO); Why or why not?_____

_____;

When compared with other production costs (manure, fertilisers, seeds), do you consider pesticide prices:

VERY EXPENSIVE ¦ EXPENSIVE ¦ REASONABLE ¦ CHEAP

29- Are you satisfied with the efficacy of the application methods you use? (YES/NO); why or why not?_____

_____;

do you consider that your application costs are:

EXTREMELY HIGH ¦ HIGH ¦ REASONABLE ¦ LOW

30- To what degree does the timing of harvesting affect the application of pesticides? _____

_____

_____

IV- FUTURE

31- Do you think that losses caused by current pest problems will (INCREASE / STAY THE SAME / DECREASE / DO NOT KNOW) in the next 5 years? Why or why not?_____

_____

32- Do you think that the number of different pests affecting your crops will (INCREASE / STAY THE SAME / DECREASE / DO NOT KNOW) in the next 5 years? Why or why not?_____

_____

_____

33- Do you foresee any difficulties in the future controlling pest problems that you now control satisfactorily ?
(YES/NO/DO NOT KNOW); (if Yes, which and why?) _____

_____

_____

Survey no._____

34- What improvements do you think would be most helpful in the future in order to improve pest control on your crops?

_____ MORE EFFECTIVE PESTICIDES
_____ SAFER PESTICIDES
_____ CHEAPER PESTICIDES
_____ BETTER SPRAYING EQUIPMENT
_____ MORE INFORMATION ON PESTICIDES & APPLICATION METHODS
_____ RESISTANT CULTIVARS
_____ NON-CHEMICAL CONTROL METHODS
_____ EFFECTIVE ADVISORY SERVICES
_____ MORE INFORMATION ON PESTS AND LOSSES
_____ OTHERS_____
_____
_____
_____ NO CHANGE, HAPPY WITH THE PRESENT SITUATION

V- CHARACTERISATION OF GROWERS

35- At what time of the year do you buy pesticides?_____
_____

36- Do you consider that the information available on the label of pesticide packages is : _____

a)UNNECESSARY b)EXCESSIVE
c)HELPFUL d)ESSENTIAL

37- Some people hold the opinion that it is possible to fight insect pests with other beneficial insects. What do you think about that?_____
_____
_____
_____

38- Some people hold the opinion that it is possible to fight soil pest problems (soil diseases, nematodes, weeds) with "SOLARIZATION" (solar heating of the soil covered by thin plastic mulching). What do you think about that?_____
_____
_____

39- Do you grow resistant cultivars as a way to control pest problems? (YES/NO). Why or why not?_____
_____
_____

40- Do you have any harvest insurance for your greenhouse crops? _____; is this common among your neighbours?_____
_____

Survey no.___

41- When you use a pesticide do you use it because it always increases the yield or do you use it because sometimes it prevents serious losses?_____

_____

_____

42- Which age group are you in?

≤ 20 21-30 31-40 41-50 51-60 >60

43- What is your educational background ?_____

_____

44- Is there anything I have missed concerning pest problems and control methods which you think is important?_____

_____

_____

THANK YOU VERY MUCH
for your *PARTICIPATION*

NOTES

APPENDIX III

3.1 - PESTICIDE RESIDUES FOUND ON VEGETABLES COLLECTED IN GREENHOUSES AND WHOLESALE MARKETS IN PORTUGAL

REGION (**)	YEAR	CROPS	No OF SAMPLES	% OF SAMPLES WITH PESTICIDE RESIDUES	PESTICIDES DETECTED AND % OF SAMPLES WITH RESIDUES OF EACH PESTICIDE	SAMPLES WITH RESIDUES ABOVE MRL VALUES INTERNATIONALLY ACCEPTED		SOURCE
						No OF SAMPLES	PESTICIDES	
W E S T	1979	tomato	2	50	dithiocarbamates (50) vinclozolin (50)			Falcão *et al.*, 1982a
	1979	sweet pepper	1	100	vinclozolin (100)			Falcão *et al.*, 1982a
	1982	strawberries	4	100	dicofol (100) tetradifon (100) dichlofluanid (50)			Falcão *et al.*, 1982a
	1983	tomato	9	100	dithiocarbamates (78) vinclozolin (56) procimidone (22) folpet (22)	3	dithiocarbamates	Ferreira *et al.*, 1983
	1983	green beans	41	88	vinclozolin (80) dithiocarbamates (22) dicofol (7) tetradifon (7) pirimicarb (5) iprodione (2) folpet (2)	1	dithiocarbamates	Ferreira *et al.*, 1983
	1984	tomato	10	30	dithiocarbamates (30) vinclozolin (20)			Frutuoso *et al.*, 1984
	1984	sweet pepper	3	0				Frutuoso *et al.*, 1984
	1986	tomato	17	100	dithiocarbamates (94) vincozolin (18) iprodione (12) procymidone (12) methamidophos (6) fenamiphos (6)	1	fenamiphos	Correia *et al.*, 1986a
	1986	green beans	5	100	vinclozolin (80) dithiocarbamates (60) dichlofluanid (60) iprodione (60) procymidone (20) fenamiphos (20) (*)			Correia *et al.*, 1986a

Appendix III - (Cont.)

REGION (**)	YEAR	CROPS	No OF SAMPLES	% OF SAMPLES WITH PESTICIDE RESIDUES	PESTICIDES DETECTED AND % OF SAMPLES WITH RESIDUES OF EACH PESTICIDE	SAMPLES WITH RESIDUES ABOVE MRL VALUES INTERNATIONALLY ACCEPTED		SOURCE
						No OF SAMPLES	PESTICIDES	
		tomato	20	50	dithiocarbamates (30) vinclozolin (20) folpet (15) iprodione (10) dicofol (10) tetradifon (10)			
		sweet pepper	7	71	vinclozolin (71) dithiocarbamates (43)			
	1							Ferreira
	9							*et al.*,
	8	strawberries	19	84	vinclozolin (53) (*) dicofol (53) iprodione (42) tetradifon (26) dithiocarbamates (5)	3	dicofol	1982
	2							
		melon	2	50	dicofol (50) tetradifon (50) fenarimol (50)			
A								
L		cucumber	2	50	vinclozolin (50)			
G								
		tomato	10	70	dithiocarbamates (50) procymidone (20) vinclozolin (10)			
A								
R	1							Falcão
	9	strawberries	11	82	dithiocarbamates (64) vinclozolin (64) iprodione (27) dicofol (18) tetradifon (18) dichlofluanid (9)	3	dithiocarbamates	*et al.*,
V	8							1983
	3							
B								
		tomato	12	100	dithiocarbamates (92) vinclozolin (58) iprodione (42) procymidone (25)			
	1	green beans	6	83	dithiocarbamates (50) vinclozolin (33 procymidone (17) iprodione (17)	2	dithiocarbamates	Frutuoso
	9							*et al.*,
	8							1984
	4							
		strawberries	7	100	vinclozolin (100) iprodione (29)			

Appendix III - (Cont.)

REGION (**)	YEAR	CROPS	No OF SAMPLES	% OF SAMPLES WITH PESTICIDE RESIDUES	PESTICIDES DETECTED AND % OF SAMPLES WITH RESIDUES OF EACH PESTICIDE	SAMPLES WITH RESIDUES ABOVE MRL VALUES INTERNATIONALLY ACCEPTED		SOURCE
						No OF SAMPLES	PESTICIDES	
		strawberries (cont.)			procymidone (14) dithiocarbamates (14)			
		sweet pepper	3	100	dithiocarbamates (67) vinclozolin (67) iprodione (33)			
	1984	lettuce	3	33	vinclozolin (33)			Frutuoso et al., 1984
		cucumber	1	100	procymidone (100) iprodione (100)			
		aubergine	1	100	dithiocarbamates (100) procymidone (100)			
		tomato	17	76	dithiocarbamates (76) iprodione (35) vinclozolin (18) procymidone (12)	4	dithiocarbamates	
ALGARVE		strawberries	13	100	vinclozolin (85) dithiocarbamates (23) dicofol (23) tetradifon (23) iprodione (15)	1	dithiocarbamates	
		lettuce	7	14	iprodione (14) metalaxyl (14)			Magalhães, in press
	1985	green beans	6	83	dithiocarbamates (67) vinclozolin (17) iprodione (17)	2	dithiocarbamates	
		sweet pepper	4	100	dithiocarbamates (100) vinclozolin (25) iprodione (25)	2	dithiocarbamates	
		aubergine	2	100	vinclozolin (100) iprodione (50)			
		cucumber	1	100	pyrazophos (100)			
		melon	1	0				
		courgette	1	0				

Appendix III - (Cont.)

REGION (**)	YEAR	CROPS	No OF SAMPLES	% OF SAMPLES WITH PESTICIDE RESIDUES	PESTICIDES DETECTED AND % OF SAMPLES WITH RESIDUES OF EACH PESTICIDE	SAMPLES WITH RESIDUES ABOVE MRL VALUES INTERNATIONALLY ACCEPTED		SOURCE
						No OF SAMPLES	PESTICIDES	
ALGARVE	1986	strawberries	14	100	vinclozolin (93) dithiocarbamates (57) iprodione (57) dicofol (57) procymidone (43) tetradifon (14) dichlofluanid (7)	3	dithiocarbamates	Correia *et al.*, 1986b
		lettuce	3	0				
		tomato	48	67	vinclozolin (48) dithiocarbamates (38) iprodione (8) dicofol (6) dichlofluanid (2)	1	dithiocarbamates	Falcão *et al.*, 1982b
(***)	1982	lettuce	6	33	dithiocarbamates (17) parathion (17)	1	dithiocarbamates	
		strawberries	14	100	dicofol (93) dithiocarbamates (50) vinclozolin (43) dichlofluanid (14) iprodione (7)	1	dithiocarbamates	
	1983	tomato	10	0				Frutuoso & Ribeiro, 1983

(*) - Not cleared to be used on this crop, at this date, according to the authors.
(**) - Samples obtained from growers in the mentioned area.
(***) - Samples obtained in wholesale markets around Lisbon.

APPENDIX IV

4.1 - EXTRACTS OF THE EXPERT SYSTEM FOR CONTROL OF GREY MOULD AND CATERPILLARS ON GREENHOUSE TOMATOES

```
do (start).

topic start.
   window('Introduction to the system').
   say('

   This is a demonstration prototype Expert system
   for pest control on greenhouse vegetable crops
   in Portugal.
   The system was developed at the SILWOOD CENTRE FOR
   PEST MANAGEMENT, using the "Knowledge Pro" tool.

        System developer: Antonio M. M. Mexia
                     1989      ').
   close_window().
   do('choose crop').
end.(* start *)

topic 'choose crop'.
   window('What Crop?').
   set_single_valued(crop).
   ask('

  Do you want to have Ptmpest controlPtm information
  on which crop?',crop,¡tomato,'green beans',melon,'sweet pepper',
  cucumber,lettuce,strawberries¿).
   close_window().

   if ?crop is tomato then do (tomatoes).
   if ?crop is 'green beans' then do (crop_empty).
   if ?crop is melon then do (crop_empty).
   if ?crop is 'sweet pepper' then do (crop_empty).
   if ?crop is cucumber then do (crop_empty).
   if ?crop is lettuce then do (crop_empty).
   if ?crop is strawberries then do (crop_empty).

   topic crop_empty.
      window('Not available')
      and say ('

  Only tomatoes may be chosen at this time.
  Information on other crops will be developed
  as soon as possible.
```

```
  Press space bar or enter to continue.') and close_window().

      reset ('choose crop').
      repeat do ('choose crop')
      until ?crop is tomato.

   end.(* Crop_empty *)
end.(* choose crop *)

          ·····································

topic tomatoes.
   window('What pest problem?').
   set_single_valued('tomato problems').
   ask('

  From the following list, which pest problem are you
  worried about?','tomato problems',¡'grey mould','late blight',
  'powdery mildew',caterpillars,'spider mites','russet mites',
  nematodes,bacteria¿).
   close_window().
   do(?'tomato problems').

   topic 'grey mould'.
      window('disease symptoms').
      set_singe_valued(symptoms).
      ask('

   Are there any Ptmgrey mould symptomsPtm on the plants?',
   symptoms,¡yes,no¿).
      close_window().
      do(?symptoms).

      topic yes.
         window('location of symptoms').
         ask('
    Where are the symptoms of the disease?','tomato parts',¡leaflets,
    petioles,stems,flowers,fruits¿) and close_window().
         do(?'tomato parts').
      end.(* yes*)

      topic no.
         do('phenological stage').
      end.(* no *)

      topic 'grey mould symptoms'.
         window('grey mould symptoms',,,,,,71,15).
         say('
    Grey mould, a disease caused by the fungi Ptfblack Ptbwhite Botrytis
    cinereaPtf white Ptbblack Pers., can attack all the aerial parts of
    the plant, producing small lesions more or less circular in shape,
    light brown to grey in colour, which later become large, coalescing.
    Under Ptmcool, humid weatherPtm, when grey mould spreads aggressively
    on its host, a large mass of PtmconidiophoresPtm is formed, bearing
    oval, single cell PtmconidiaPtm densely aggregate, giving the
    characteristic aspect of the grey mould infection.
    The infected tissues develop a Ptmsoft rotPtm later.
```

```
"Irrespective of the quality of symptoms description, these
should be confirmed with a good photograph or ilustration
in a technical manual).') and close_window().
  end.(* grey mould symptoms *)
```

.....

```
  topic 'phenological stage'.
     window('Phenological stage of the crop?').
     ask('

Is the first truss of the plants at flowering stage, or
are the tomato plants already after this phenological
stage?',conditions,¡yes,no¿).
     close_window().
     do(?conditions).

     topic yes.
        do('weather conditions').
     end.(* yes *)

     topic no.
        do('do nothing').
     end.(* no *)
  end.(* phenological stage *)

  topic 'weather conditions'.
     window('Present weather conditions?').
     set_single_valued('present weather').
     ask('

Considering that grey mould is particularly destructive
under Ptmcool, humid weatherPtm conditions, what are the
prevalent weather conditions at present?','present weather',¡
'rainy and cool',
'cloudy and cool',
'cloudy and hot',
'clear and hot'¿).
     close_window().
     do(?'present weather').

     topic 'rainy and cool'.
        do('chemical application').
     end.(* rainy and cool *)

     topic 'cloudy and cool'.
        do('meteor. forecasting').
     end.(* cloudy and cool *)

     topic 'cloudy and hot'.
        do('meteor. forecasting').
     end.(* cloudy and hot *)
```

```
    topic 'clear and hot'.
       do('do nothing').
    end.(* clear and hot *)
  end.(* weather conditions *)

        ....................................

  topic 'chemical application'.
    window('begin spraying').
    say('

You must reassess Ptmother control methodsPtm for grey mould
and begin chemical control IMEDIATELY.').
    close_window().
    do(pesticides).
  end.(* chemical application *)

  topic pesticides.
    window('Cleared Pesticides',,,,,,,14).
    say('
The following list indicates the active ingredients cleared
at present to be used against grey mould on tomatoes:

        Ptmbenomy1Ptm
        PtmdichlofluanidPtm
        PtmiprodionePtm
        PtmprocymidonePtm
        PtmvinclozolinPtm


(You have technical information available for each of them:
  Select the desired pesticide with F3 and then press F4.)').
    close_window().
    do('pesticide strategy').
  end.(* pesticides *)

        ....................................

  topic 'other control methods'.
    window('other control methods',,,,,,,14).
    say('

The only alternative methods are cultural methods, linked
with: a) reduction of disease inoculum;   b) reduction of
plant susceptibility to the pathogen;   c) elimination of
environmental conditions favourable to the pathogen inside
greenhouses.
In unheated greenhouses there are very few possibilities
to control environmental conditions, apart from PtmventilationPtm.
All the infected parts of the plant should be removed as
soon as possible and all senescent leaves, through regular
PtmdeleafingPtm. All the Ptmsusceptible conditionsPtm affecting
the crop susceptibility to grey mould should also be avoided.
                        ¡press  pgdn  for more information¿
```

```
  There are no tomato cultivars resistant to grey mould, and
  the differences in susceptibility to the disease amongst
  different cultivars seems to be linked with differences
  in the microclimatic conditions inside the plant canopy.

  Biological control is far from being available to commercial
  growers in spite of sucessful experimental results with
  antagonistic fungi, like Ftfblack Ftbwhite Trichoderma harzianum Ftfwhite
  Ftbblack. ').
       close_window().
    end.(* other control methods *)

                .....................................

 topic deleafing.
    window('deleafing explanation',,,,,,,17).
    say('
  Deleafing consists in removing regularly the lower leaves
  of the plant, by breaking off petioles close to the stem.
  Deleafing begins before the first picking, when fruits in
  the first truss begin ripening (changing colour) or when
  the 4th truss reaches setting. Usually first deleafing
  removes all the leaves up to the first or second truss and
  subsequently this operation is repeated regularly during
  the season, keeping at least 4 trusses with leaves along
  the stem. All the infected leaves should be removed either,
  irrespectively of their position.
  the reasons for deleafing are: a) promoting early ripening;
  b) allowing easy picking; c) improving air movement, light
  conditions and reducing periods with high humidity in the
  lower part of the canopy; d) reducing senescent leaves and
  removing infected leaves in order to reduce infection by
  pathogens.').
    close_window().
 end.(* deleafing *)

 topic 'repeat tomato pests'.
    window('Rerun tomato pests?').

    set_single_valued(choices).
    ask('
   Do you want to run the system again for this pest problem,
   or any other tomato pest problem?',choices,¡yes,no¿).
    close_window().
    do(?choices).

    topic yes.
       do(tomatoes).
    end.(* yes *)

    topic no.
       do('repeat crops').
    end.(* no*)
  end.(* repeat tomato pests *)

end.(* tomatoes *)

                .....................................
```