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Recent developments and market opportunities for IPM in greenhouse tomatoes in southern Europe

Consequences for advanced IPM toolboxes and greenhouse engineering

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Recent developments and market opportunities for IPM in greenhouse tomatoes in southern Europe

Consequences for advanced IPM toolboxes and greenhouse engineering[1]

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[1] The original title of the Deliverable and the Milestone in Work Package 7 of the Pure Programme is 'Report on innovations in greenhouse engineering and advanced IPM tool boxes with respect to their impact on pest communities'.

Recent developments and market opportunities for IPM in greenhouse tomatoes in southern Europe; Consequences for advanced IPM toolboxes and greenhouse engineering

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Preface

Traditionally crop protection in greenhouse horticulture has been based on the use of pesticides. Indeed, the use of pesticides is still very important in some European regions. Consequently, chemical control of pests and diseases causes serious problems in European horticulture: (1) it is not always efficient, mainly due to the difficulties to reach and locate some pests; (2) it can cause farmer health problems; (3) it can negatively affect beneficials that contribute to keeping secondary pests under control; (4) it can generate problems of resistance; (5) it can cause serious marketing problems because of the possible presence of residues on horticultural products; and (6) it can give rise to important environmental and sustainability issues.

To tackle these problems the EU Directive on sustainable use of pesticides (Directive 2009/128/EC) enforces the implementation of efficient and sustainable alternative pest control methods. The Pesticides Use-and-risk Reduction in European farming systems with Integrated Pest Management (PURE) programme is designed to reduce the use and risks of chemicals through Integrated Pest Management (IPM). Work package 7 (WP7) of the PURE programme focuses on greenhouse tomatoes. WP7 includes four tasks. This deliverable presents the results of task 1 (greenhouse technological packages and tactical packages design) and task 2 (ex ante assessment).

In task 1 and task 2 the current situation and developments in the greenhouse tomato sector and the marketing of tomatoes in Europe, in relation to crop protection, are investigated in interaction with stakeholders. The use of chemicals in the cultivation of greenhouse tomatoes has traditionally been the highest in the south of Europe. Therefore, the research is focused on the southern regions Spain, Italy and the south of France. Because of the competition on the international market the situation in the Netherlands and Belgium and the export to Germany is also taken into account. The results of this investigation are useful to give direction to the experiments in task 3 and the ex post assessment in task 4.

The leader of task 1 is Alberto Urbaneja of the Instituto Valenciano de Investigaciones Agrarias (IVIA) from Spain and the leader of task 2 is Nico van der Velden of the Agricultural Economics Research Institute (LEI Wageningen UR) from the Netherlands.

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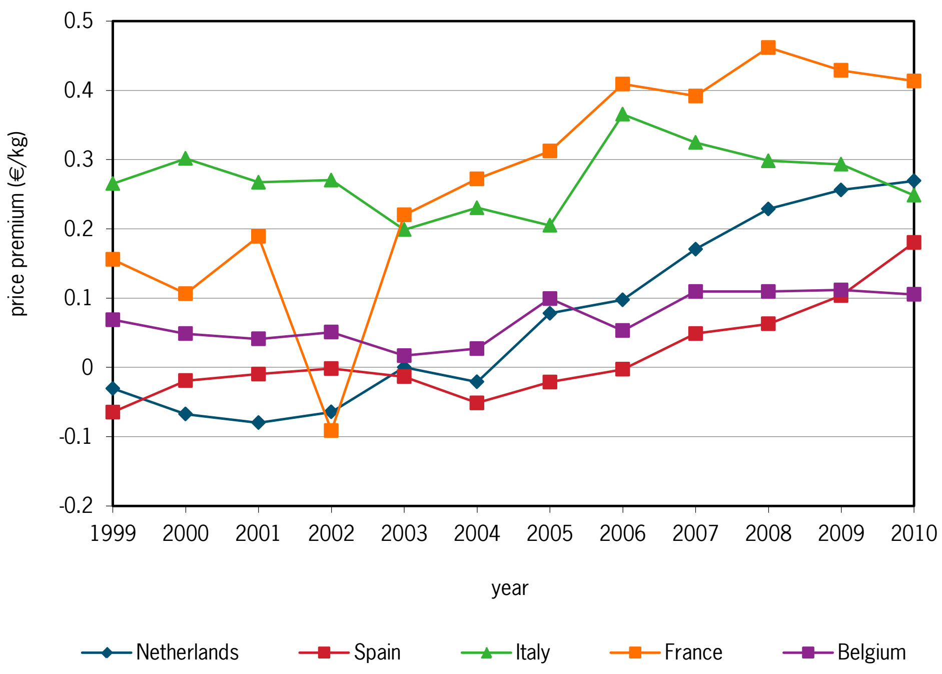
Summary

S.1 Key findings

The market for greenhouse tomatoes requires a production system with lower use and risks of pesticides. These requirements culminate in the tight restrictions on residues for German retailers, both in number and in levels of residues. Germany is an important import country for tomatoes because of the size of the German market. Furthermore, exports to Germany entail a price premium[1] (Figure S.1). For that reason the revenues of IPM in greenhouse tomatoes are more important than the costs. Consequently, the experiments in task 3 and the ex post assessment in task 4 of work package 7 of the Pure programme should focus on IPM strategies by which the German residue restrictions can be respected.

Figure S.1 **Price premium for exports to Germany by country**



S.2 Complementary findings

The major challenges in relation to IPM in greenhouse tomatoes are the diseases (airborne and soil born) and nematodes. Control of pests with IPM is technically largely possible. For control of airborne diseases research should focus on greenhouses with better ventilation options and improvements in this area and tolerance of the tomato plants. For soil pathogens (diseases and nematodes) research should focus on non-chemical alternatives: soil solarisation, root stocks and substrate. The economic opportunities of these alternatives are best in the long winter crops. For disease control the development of antagonists is desired.

[1] The price premium refers to the extent to which the export price to Germany is higher than the average price of the other exports from the individual countries.

A better understanding of the potential of plant health and soil quality as a means to reduce the dependency of chemical pests control is needed.

S.3 Methodology

In task 1 and 2 of work package 7 of the PURE programme, the situation and developments in the greenhouse tomato sector, and the marketing of tomatoes in Europe in relation to crop protection, are investigated by participatory research in interaction with stakeholders. The use of chemicals has traditionally been highest in the south of Europe. Therefore, the focus of the investigation is on Spain, Italy and the south of France.

1 Introduction

Problem
Traditionally the use of pesticides is very important in crop protection in greenhouse horticulture. The Pesticides Use-and-risk Reduction in European farming systems with Integrated Pest Management (PURE) programme is designed to reduce the use and risks of chemicals through Integrated Pest Management (IPM).
Work package 7 (WP7) of the PURE programme focuses on greenhouse tomatoes. WP7 includes four tasks:
1. Greenhouse technological packages and tactical packages design with stakeholders;
2. Ex ante assessment including stakeholders' input;
3. IPM solutions testing:
   3a. On-station experimentation with candidate IPM solutions;
   3b. On-farm testing of IPM solutions and dialogue with stakeholders;
4. Ex-post assessment including stakeholders' input.

Chemicals in tomatoes are not only used for controlling pests (insects, mites and nematodes) but also for the control of diseases (airborne and soil born). Diseases are also taken into account in this study.
The use of chemicals in the cultivation of tomatoes depends on the outdoor climate, the climate inside the greenhouse, the technical level of the greenhouse structure, technical equipment in the greenhouses, growing periods, the market situation and so on. All these aspects are interrelated. Hence the subject is quite complex.

Purpose and focus
Task 1 and task 2 aim to investigate the situation and developments in the greenhouse tomato sector, and the marketing of tomatoes in Europe, in relation to crop protection and in interaction with stakeholders. Focal points in this investigation are sector structure (acreage, farms and regions), greenhouses and technology, growing periods and tomato types, exports and market prices, main pests and diseases and main control methods. This information is necessary to give direction to the experiments in task 3 and the ex-post assessment in task 4.
The use of chemicals in the cultivation of tomatoes has traditionally been highest in the south of Europe, mainly because of the planting of the crop in the summer period with high pest infestation from outside the greenhouses (Van der Velden et al., 2004). Spain, Italy and France are therefore primarily taken into account. The Netherlands and Belgium are also taken into account because of the high level of IPM in these countries and the important position of the Netherlands on the European export market of tomatoes.
The investigation focuses on IPM. IPM is a broad concept which can be summarised as a sustainable approach to managing pests by combining biological, cultural, physical and chemical tools in a way that minimises economic, health, and environmental risks. Nevertheless, in this study we will consider to be IPM those pest management programmes that imply at least the use (either by release or by conservation) of one natural enemy to control pests and diseases. Of course IPM might include more natural enemies in practice. Organic farming is not taken into account.

Approach
The approach of task 1 and 2 is combined in two steps:
1. Gathering available statistical information;
2. Interviews with stakeholders and analysing the information.

In step 1 available statistical background information about the greenhouse sector in general and the tomato greenhouse sector in Spain, Italy and France in particular is gathered in a desk study. This information is compiled in a working document per country. In addition export data (quantity, values and prices) of tomatoes per country are studied by using the European export database (Eurostat).

In step 2 participatory research is done through about 40 interviews with stakeholders mainly in Spain and Italy and some with stakeholders in France, Belgium and the Netherlands according to the methodology developed by Byerlee et al. (1980), Van der Velden et al. (2004a) and Van der Velden et al. (2004b). The interviews are conducted as semi-structured conversations about aspects in crop protection in greenhouse tomatoes. A checklist of topics was made for the interviews (Appendix 1).

Interviews have been conducted with input suppliers, seed companies, nurseries, a bank, tomato growers, growers' organisations, government representatives and research centres in Spain and Italy. The areas Almería and Murcia in Spain and Campania, Lazio and Sicilia in Italy were visited. The interviews dealt with the situation in 2010/2011, developments and trends in the preceding years and expectations about the future. Not all subjects have been discussed with all experts. The interviews were targeted at the expertise of the experts. The information of step 1 (greenhouse sector and market information) was used as input for the interviews with the experts.

The information of step 1 and 2 is analysed in the ex-ante assessment. For a detailed cost-benefit analysis, a distinction has to be made between growing periods in the different countries; also, more information is needed than available. Therefore, a more qualitative analysis has been performed. Combining and checking the consistency of the information is very important in this analysis.

Reading guide
In the next five chapters of this deliverable a description of the situation and developments of the greenhouse tomato sector of the Netherlands, Belgium, France, Spain and Italy is given. The deliverable is structured from north to south. Chapter 7 analyses the export of tomatoes of the countries and Chapter 8 contains the synthesis. The conclusions and recommendations are presented in the last chapter.

2 The Netherlands

Sector structure
In the Netherlands, greenhouse tomatoes are grown on an area of 1,600-1,700 ha and the acreage is increasing, especially the area with artificial lighting. The cultivation takes place mainly in the western regions nearby the coast, since those regions have more sunlight and a moderate outdoor climate, but tomato crops are also grown in other parts of the country. During the last decade a large scaling up occurred.

Substrate, greenhouse types and technology
Cultivation takes place on substrate in almost the entire area. Mainly rock wool is used. Almost all tomatoes are grown in relatively high glasshouses by using a climate computer, heating, CO_2 enrichment, energy screens, automatic ventilation, and watering. In short, a lot of technology is used for conditioning the greenhouse climate and improving the physical production and the quality of the products.

Types of tomatoes, growing periods and physical production
Most of the area is cultivated with round truss tomatoes but loose tomatoes are also grown and the area of other types of tomatoes such as smaller, round, plum, cherry and cocktail tomatoes is increasing. The new types are harvested as truss tomatoes (tomatoes on the vine) and loose tomatoes.

Most companies have one crop per year. The crop is planted in late November/early December. The harvest starts in late February/early March and continues until late October/early November. On a part of the area - approximately 15-20% - artificial lighting is applied. In this area the tomatoes are planted approximately two months earlier. As a result tomatoes are harvested and sold year-round in the Netherlands.

Because of the long growing period and the technological applications the physical production in kg per m^2 is high and has significantly increased over the years. The level of physical production depends on the type of tomato; in the case of smaller types the harvest is lower. The average physical production per year of the most common type (round truss tomatoes) is about 60 kg/m^2, and of the smallest types it is about 30 kg/m^2.

Export
The major part of the tomato production is exported. The export share is estimated at about 90%. The precise proportion is not known because the export statistics also include exports of imported tomatoes (re-export). Exports are thus even larger than the Dutch production.

Major pests and diseases
The main pests are the greenhouse whitefly *(Trialeurodes vaporariorum)*, spider mites, aphids, rust mite and caterpillars. The tomato borer, *Tuta absoluta*, is occasionally present but has not really established itself.

A possible virus problem relates to the Pepino Mosaic Virus (PepMV). This virus is mechanically transmissible and is occasionally present.

The most important diseases are *Botrytis* and downy mildew. Soil pathogens, except for crazy roots (bacterial degradation), are not really a problem because of the use of substrate.

Almost all companies use bumble bees for pollination of the tomatoes. As a result, the choice of chemicals is limited to selective chemicals. This already introduced some integrated pest control but also secondary pests (rust mites).

Control methods
The pests are controlled mainly biologically in combination with sticky roller traps. Chemicals are occasionally used. Predators are released and distributed equally throughout the greenhouse but sometimes at hot spots in the greenhouse where the pest occurs. IPM, then, is used on nearly the total acreage.

For disease control, the climate in the greenhouse (heating and ventilation) is very important and chemicals are used. Sulphur evaporators are used against powdery mildew. The health of the crop in relation to diseases receives increasingly more attention. The health of the crop will depend, inter alia, on the thickness of the plant, and this has a relation with the heating temperature.

New development
There is a new development in the further conditioning of the greenhouse climate. This is the suction of dry air from and the removal of moist greenhouse air to the outdoor environment. As a result, moisture is removed and there is less need to ventilate through the windows in the roof and the energy screen can remain closed for a longer time. This development reduces the heat demand and saves fossil fuel consumption (Van der Velden et al., 2011).

The development is inspired by the closed greenhouse with solar heat recovery. The closed greenhouse was used in tomato crops on a modest scale but is on its return now.

The air treatment is primarily used to reduce the energy demand and to improve the tomato production but it also has an influence on the humidity in the greenhouse. In addition, the greenhouse climate (temperature and humidity) will be more uniform. Both can affect pests and diseases.

3 Belgium

Sector structure, substrate, greenhouse types and technology

In Belgium greenhouse tomatoes are grown on an area of 400-500 ha and this area has remained the same during the past few years. The cultivation takes place mainly in the northern part of the country and especially in the region of Antwerp.

The cultivation takes place on substrate on more than 90% of the entire area. Mainly rock wool is used. Almost all tomatoes are grown in glasshouses that use a climate computer, heating, CO_2 enrichment, energy screens, automatic ventilation, and watering. The main growing period is very similar to the Netherlands, only planting is on average some weeks later. Some Belgian tomato growers use lighting. The Belgian greenhouse tomato sector seems technically similar to that of the Netherlands. Internationally the Netherlands and Belgium are considered as one tomato growing area.

Types of tomatoes, physical production and exports

When we look at the type of tomatoes, we see some differences between Belgium and the Netherlands. In Belgium also different types of tomatoes are grown but the main types are beef tomatoes and the bigger truss tomatoes. Both types comprise approximately half of the tomato production. Because of the bigger tomato types the average physical production per year is somewhat higher than in the Netherlands.

The major part of the tomato production is exported. The export share is estimated at about 80-90%. The main tomato types for export are also beef tomatoes and truss tomatoes.

Major pests and diseases and control methods

The main pests and diseases and control methods are very similar to the Netherlands and are not described further. IPM is also used on nearly the total acreage.

4 France

Sector structure
The total acreage of greenhouse tomatoes in France is about 1,800 ha and decreasing, while the production in tonnes is stable. Greenhouse tomatoes are grown in two regions: the west and the south. The west comprises the areas Normandy and Brittany (extreme west) and Centre, Pays-de-Loire and Poitou-Charentes (west). The south concerns the regions of Aquitaine and Midi-Pyrenees (south-west) and Corsica, Languedoc-Roussillon, Provence-Alpes-Côte d'Azur and Rhône-Alpes (south-east). There are differences between the regions in terms of greenhouse types, applied technologies, growing periods and type of tomatoes. In general greenhouse areas in the west used more technology while in the south the greenhouses are older and low tech.

Greenhouse and technology
In the west and in the south-west, tomatoes are mainly grown on substrate and in glasshouses with the use of climate computers, heating, CO_2 enrichment and energy screens, next to multi-span greenhouses with plastic cover. In the west lighting is also used. In the south-east mainly plastic greenhouses are used, both simple tunnels and multi-span greenhouses. Glasshouses are also used. The multi-span greenhouses and glasshouses with heating are located in the western part of the south-east. The companies with tunnels in the south-east often have a number of tunnels (approximately 500-700 m^2 per tunnel) and the average farm size is below 1 ha. In the west and the south-west irrigation and fertilisation are commonly automated by computer. In the south-east this is not the case on a large part of the area with tunnels. Moreover, in the west, the south-west and the western part of the south-east more technology is used than in the eastern part of the south-east. Throughout France about 1,100 ha are heated and about 700 ha are not heated.

Growing periods and physical production
The main growing period in heated glasshouses is planting in December/January, starting harvest in March and ending harvest in November. This growing period is about ten months and is somewhat shorter than in the Netherlands and Belgium but longer than in Spain and Italy.

In the greenhouse types without heating the growing periods are shorter and more dispersed throughout the year. Sometimes two crops are planted in succession. The main planting period is September, starting harvest in December and ending harvest in May/June. The unheated growing periods correspond with Spain and Italy. So differences in use of technology between regions are associated with differences in growing periods.

In heated greenhouses, the average physical production is about 40 kg per m^2 per year and in unheated greenhouses about 15 kg per m^2 per year.

Tomato types
In France different types of tomatoes are grown. The common types are Coeur di Boeuf, Marmande, plum tomato, intermediate type, cherry tomatoes and cocktail tomatoes. Both loose and truss tomatoes are harvested. In the heated greenhouses mainly the more expensive types of tomatoes are grown and the focus is on smaller types.

Exports
The major part of French tomato production is sold in France, export includes only a limited share. The tomatoes produced in unheated greenhouses are mainly sold locally but for the heated tomatoes export is more important. The exact share of exports is not known because the export statistics also include re-export. Re-exports concern imported tomatoes from Morocco exported by France. The share of exports of the French production is estimated at less than 30%.

Main pests and diseases

The main pests in France are thrips, whiteflies *(Bemisia tabaci)*, spider mites, leaf miners *(Tuta absoluta)* and rust mite *(Aculops lycopersici)*. Also the greenhouse whitefly *(Trialeurodes vaporariorum)*, caterpillars, aphids and nematodes occur. Recently Tuta absoluta was the biggest problem but the problem with this pest decreased.

The most important potential virus attack concerns the Tomato Yellow Leaf Curl Virus (TYLCV), which is spread by the whitefly *(Bemisia tabaci)*. TYLCV in combination with *B. tabaci* is a problem in the south.

A distinction is made between airborne and soil-born diseases. The main airborne diseases are *Botrytis* and powdery mildew *(Oidium)* and the most important soil-born disease is *Phytophthora.* The airborne diseases and soil pathogens (soil-born diseases and nematodes) are mostly a problem in the south of France.

Control methods

In France chemicals are important in crop protection. For the pollination of tomatoes bumble bees are used on a part of the area. This is mainly the area with heating. The use of bumble bees entails that broad-spectrum chemical agents are no longer used for plant protection, because the bumble bees need to survive.

IPM is used on about two-thirds of the area and mainly concerns the area with heating. IPM is used against pests. Mass trapping is also used. To keep out the insects, nets are used in the south-east, especially in the western part of the south-east. *Macrolophus pygmaeus* is used as predator against whitefly. French tomato growers do not want to use *Nesidiocoris tenuis* because it may became a pest due to its zoophytophagous behaviour. Predatory bugs, mainly *M. pygmaeus*, are used against *Tuta absoluta*.

Tolerant tomato varieties are used against TYLCV and the controllability of the whiteflies is also important.

The control of diseases mainly takes place chemically. The use of heated glasshouses with automatic climate control is also important for the controllability of diseases.

The control of soil pathogens (diseases and nematodes) in unheated greenhouses is mainly done by the use of chemicals. Tolerant rootstocks are also applied. Heated tomatoes are mainly grown on substrate and this is important to control soil pathogens.

5 Spain

Sector structure
The total acreage of greenhouses tomatoes in Spain is about 20,000 ha. The main growing areas are Almería and Murcia, both regions in the southeast of Spain. In Almería the acreage is approximately 8,000 ha and in Murcia about 2,000 to 3,000 ha. Of the other regions Granada (Motril, west of Almería) with about 2,000 ha, the Canary Islands with about 1,000 to 1,500 ha and Alicante with about 1,000 ha are also important areas. The total acreage of greenhouse tomatoes is declining. The most important reduction has recently occurred in the Canary Islands and Murcia, although in other regions the acreage is also declining.

Also in Spain a considerable scaling up has occurred. In Almería companies with less than 2 ha of greenhouses are disappearing quickly. In contrast, a number of very big companies in Murcia have stopped growing tomatoes or have reduced their acreage.

Tomato types
Different types of tomatoes are grown. The biggest type is the salad or beef tomato and the smallest are the cherry tomato and cocktail tomato. In between are the intermediate types, raf tomato, round tomato, plum tomato and roman tomato. The salad tomato, intermediate types and round tomato comprise the largest area. The intermediate types in Spain concern especially the bigger types. The small types, cocktail and cherry tomato, comprise a very small proportion of the total acreage. Both loose and truss tomatoes are harvested in Spain but loose tomatoes are the dominant type. Also in Spain relatively more traditional types of tomatoes are grown. Roughly half of the tomato production is exported. The intermediate type and round tomatoes are the most important for export.

Growing period and physical production
The cultivation takes several months to over half a year. In Almería the main growing period is the long winter crop with planting in August, starting harvest in October and ending harvest at the end of winter. After the first crop, tomatoes are planted again on a limited part of the acreage (short spring crop) or another crop is planted. The short spring crop runs roughly from April to June, although its importance is declining.

Because of the high temperatures in summer, the greenhouses are not used year round. In the summer period tomatoes are also grown outside and in spring and autumn tomatoes are grown under net houses on a limited scale. A number of big companies, especially with the traditional tomato types, strive after year-round production including growing tomatoes in different regions.

The physical production in the long winter crop is 12-16 kg/m^2 on average. In Murcia, tomatoes are more grown throughout the year and in general growing periods are shorter.

Soil and substrate
The cultivation of tomatoes in Spain takes place mainly in the (natural) soil. In Almería, this involves an applied sand mulch on clay. Every three years organic manure is added in between the beds. This cultivation layer could be seen as a 'substrate' and seems to be favourable to control soil pathogens (soil-borne diseases and nematodes).

Both in Almería and in Murcia on a limited part of the acreage (15-20%) tomato crops are grown on substrate. Perlite is the main substrate but also rock wool and coco fibre are used. The area with substrate seems to be declining.

Greenhouses and technology
The traditional Parral greenhouse is mainly used in Almería. The oldest Parral greenhouses are flat with wooden pillars covered with plastic. The height is approximately 1,80 m, the plastic is held between two

wire nets. The rainwater is discharged into the greenhouses through holes in the plastic. Ventilation is manually operated in the facades.

The Parral greenhouses evolved over the last 10-15 years. The modern Parral (Raspa y amagado) still has a plastic cover but is higher (2 to 3.5 m). The roof is not flat but saddle shaped, so the rainwater can be discharged via gutters. As a result the ventilation and the humidity control are better in the modern Parral. Nets are arranged in the ventilation openings in the roof and the facades to keep out pests.

Besides the Parral on a limited but growing part of acreage the Multi Tunnel greenhouse is used. The Multi Tunnel greenhouse has a steel structure and is covered with plastic (but without wires) and has vents in the roof and in the facades. The Multi Tunnel greenhouse has a gutter height of 3-4 m and a ridge height of 5-6 m. In this type of greenhouse, the possibilities for ventilation are better.

In the region of Murcia plastic greenhouses with wood or steel constructions are used too and on a limited part of the acreage Multi Tunnel greenhouses are used.

In both areas net greenhouses are used on a small acreage. This type of greenhouse is used for season extension (spring and autumn).

Over the past 10-15 years Almería and Murcia shifted to higher greenhouses with better ventilation in the roof and the facade. The main investment in the greenhouses consists of fans to move stagnant air. All of this creates better ventilation and humidity control. The share of Multi Tunnel greenhouses in both areas is limited (approximately 10-20%). The ventilation openings are manually operated and closed. In the Multi Tunnel greenhouses this is partly automated. In the greenhouses climate computers, energy screens, heating and CO_2 enrichment is occasionally used, also in the Multi Tunnel greenhouses. In general, heating is considered to be too expensive. In addition, a large part of the greenhouses is not suitable for heating (not flat and open). If heating is used, it will be for reducing moisture rather than heating. Fertigation is often automated.

Major pests and diseases

The main pests are whiteflies *(Bemisia tabaci)*, the tomato borer *(Tuta absoluta)*, thrips, spider mites (in summer), rust mite and sometimes caterpillars. Some years ago, *Tuta absoluta* arrived in Spain, but the incidence of this pest has decreased during the last years and nowadays it is considered almost as a secondary pest. In addition to the pests, the Tomato Yellow Curl Virus (TYLCV) is important. Attack by TYLCV could cause major economic damage. The virus is transmitted and spread by the whitefly, *B. tabaci*. Nematodes are not a major problem in Spain. This is probably due to crop rotation and the growing beds. In areas with little crop rotation nematodes are more problematic. Some years ago spider mites were a problem, but this seems to be under control now. Diseases are categorised into airborne and soil-born diseases. The main airborne diseases are *Botrytis* and powdery mildew *(Oidium)* and the most important soil-born disease is *Phytophthora*.

Control methods

Some years ago the vast majority of the acreage of greenhouse tomatoes in Spain controlled pests and diseases chemically.

For the pollination of tomatoes bumble bees are used on the major part of the area. This entails that broad-spectrum chemical agents are not used for plant protection anymore, because the bumble bees need to survive. By using more selective chemicals, the incidence of secondary pests may increase. A possible example is the rust mite that became a problem some years ago.

In the growing season 2009/10 about 20% and 2010/11 about 50% of the tomato acreage applied IPM in Almería. It is expected that this trend will continue in the season 2011/12. Most pests are biologically controlled. Effective biological agents are not available to control diseases. In Murcia biological pest control was used earlier and also a higher share of the acreage applied biological pest control. Experts estimate the penetration rate at about two-thirds to three-quarters of the area.

In both regions, the increase of IPM in tomatoes stems from a combination of internal and especially external factors. These factors are the problems with residues on the export market (Chapter 7) in combination with distrust from society and growers of large-scale chemical use, the use of bumblebees for pollination, the arrival of Tuta absoluta, the huge success in the use of biological pest control in sweet pepper in previous years, and the role of suppliers through which beneficials became available. Moreover, financial support and a training programme on the use of biological control were initiated by the governments of both Almería and Murcia.

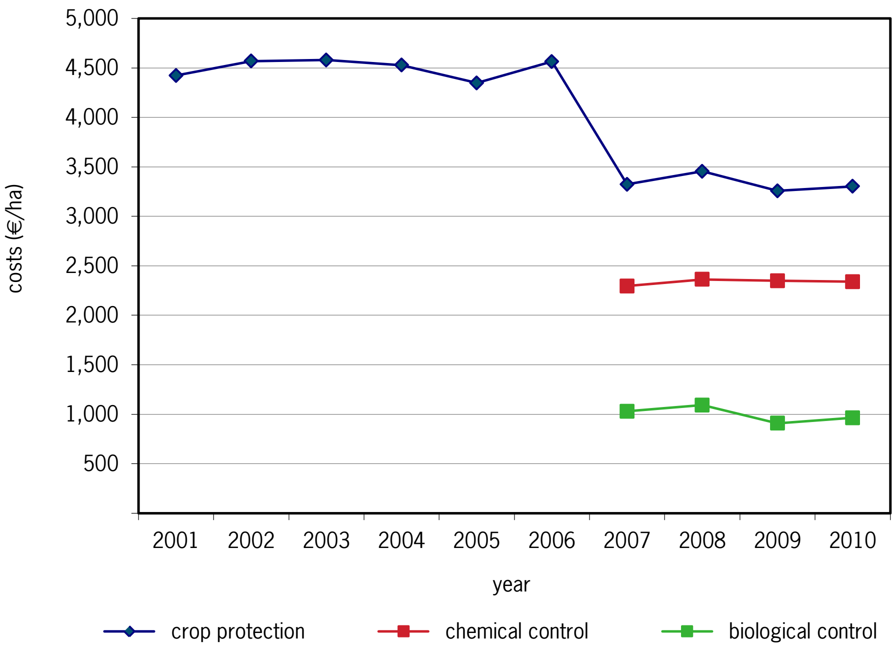
In both areas controlling pests with IPM involves a combination of control methods. The ventilation openings of the greenhouses are equipped with nets, pheromone traps are used, tolerant varieties against TYLCV are developed and especially from the beginning of the crop the mirid predator *Nesidiocoris tenuis* is released in the greenhouses. This predator is mainly used against whiteflies *(B. tabaci)* and the tomato borer *(T. absoluta)*, although it preys on other pests such as thrips, spider mites or leaf miners. The latest trend is to release Nesidiocoris tenuis in the plant nurseries. Furthermore, this predator occurs spontaneously in nature. However, *N. tenuis* could become a pest for the tomato crop when the population is too large and not enough food is available. In that case chemical control is used against *N. tenuis.*

The problems with diseases are associated with the ventilation and moisture in the greenhouses. The main problems are caused by condensation at sunrise. The diseases are controlled with chemicals. Higher greenhouses with improved ventilation options are also used. The improved ventilation of the greenhouses, however, competes with the use of nets in the ventilation openings against pests. The control of soil pathogens (diseases and nematodes) is mainly done by the use of chemicals and tolerant rootstocks. Substrate and soil solarisation are used on a small acreage (for explanations about soil solarisation, see Chapter 6).

Costs of crop protection

During the interviews several experts have reported and explained that in Spain plant protection with natural enemies of pests is cheaper than without biological control. This is also evidently reflected in Figure 5.1. This figure shows that the costs of crop protection (chemicals and beneficials) in greenhouses with vegetables in Almería declined in the season 2007/8. This year the biological control in vegetable greenhouses was especially well developed in sweet pepper.

Figure 5.1 **Average costs of crop protection (chemical and biological) in Almería (€/ha)**



Source: Estación Experimental de la Fundación Cajamar.

6 Italy

Sector structure

The total area of greenhouses with tomato in Italy is almost 5,000 ha. The tomato crop is scattered across the country. The five areas with the highest acreage are Sicily (1,533 ha), Campania (1,083 ha), Lazio (815 ha), Veneto (542 ha) and Sardegena (563 ha). The tomato production is highest in Sicily, followed by Campania, Sardegena, Lazio and Veneto. The ranking of the acreage, then, is not the ranking of the production. This is related to the level of physical production per m^2 greenhouse. In Sicily and Sardegena the physical production is over 12 and nearly 11 kg per m^2, respectively. This is higher than in the other three areas, where the average is around 7 kg per m^2.

Growing periods

The growing period varies by area. In Campania and Lazio there are roughly two growing periods. The winter-spring crop is planted in January/February, the harvest starts in May and ends in June/July. The summer-autumn crop is planted in July/August and the harvest begins in September and ends in December. Both crops take about five months and produce about eight bunches of tomatoes. When the final bunch is developed, the plant is topped. In terms of acreage, the winter-spring crop is more important. A winter-spring crop can be followed by a summer-autumn tomato crop or by another crop.

During a part of the year the greenhouse can be empty: in January because it is too cold and in the summer because it is too hot.

In Sicily there are also short winter-spring and summer-autumn crops. In addition, there is a long autumn-winter cultivation: planting begins in October to December, harvest starts in February and ends in June. In this growing period the greenhouse is not empty in January. The long autumn-winter cultivation mainly takes place in the south of Sicily, whereas the shorter crops are planted further inland. On the south coast it is warmer and the minimum temperature in January is higher.

Types of tomatoes and exports

In Italy, many types of tomatoes grown. The largest shares are the shares of cherry and plum tomato. In addition, the intermediate type, round tomatoes and specialties are grown. Also Italy is growing relatively more small tomatoes.

The tomato production is for the major part sold in Italy. The share of exports is limited to approximately a quarter of the production. The exports are mainly cherry tomatoes from Sicily. The long autumn-winter crops are mainly intended for exports.

Soil and substrate

Almost the entire acreage is grown on soil. Occasionally substrate (coconut fibre) is used, especially for cherry tomatoes.

Types of greenhouses and technology

The tomato greenhouses in Italy have a wooden or steel construction covered with plastic and ventilation openings in the facade. The ventilation openings are manually opened and fitted with nets to keep out the insects. On a limited area greenhouses have windows in the roof. Net greenhouses are used on a small part of the acreage. Climate computers, heating and CO_2 enrichment are not applied. Heating is found to be too expensive. In addition, a part of the acreage is not suitable for heating (not flat and open). Occasionally double layers of plastic are used to reduce heat radiation and to achieve a slightly higher temperature in the greenhouses. Watering is often automated. The main development is that the greenhouses have become higher and fans are used to improve ventilation and humidity control.

Major pests and diseases
The main pests are whiteflies (*Bemisia tabaci an Traleurodes vaporariorum*), the tomato borer (*Tuta absoluta*), spider mites, rust mite, thrips and caterpillars. Like in Spain the virus infection with the Tomato Yellow Leaf Curl Virus (TYLCV) is important. This virus is spread by the whitefly, *B. tabaci.*

In Italy, the infection by nematodes from soil is a major pathogenical problem. A distinction is made between airborne and soil-born diseases. The main airborne diseases are *Botrytis*, powdery mildew (*Oidium*) and *Cladosporium*, and the main soil-born diseases are *Phytophthora, Fusarium* and *Pythum*. Also in Italy soil pathogens are important.

Control methods
In Italy crop protection is mainly based on the use of chemicals. Bumble bees are used for pollination. This is particularly important in relation to the small tomato types with many fruits on a bunch. With the use of bumble bees, no broad-spectrum chemicals can be used. This could cause secondary pests and this explains the growing problems with rust mite.

Biological control of pests is applied on a very limited area (a few percent only). The area with IPM in the region of Lazio and Campania does not exceed a few dozen hectares. In Sicily, the area of IPM is larger but also limited. Resistant varieties, pheromone traps and the beneficials *Macrolophus pygmaeus* and *Nesidiocoris tenuis* are used. Contrary to Spain, *M. pygmaeus* is used more than *N. tenuis*.

The airborne diseases and soil pathogens (diseases and nematodes) are mainly controlled chemically. The soil-borne pathogens are controlled on a limited area with soil solarisation, root stocks and substrate. The last two options are too costly for short crops.

Generally IPM is not really an issue for the tomato growers in Italy. They distrust biological control and would like to see results first. In Italy, the acreage with organically grown tomatoes is higher than with IPM but the organic tomato acreage is also limited.

Soil solarisation
Soil solarisation is used in summer in empty greenhouses. The soil is covered with clear plastic and the soil is moistened. The sunlight increases the temperature of the wet soil under the plastic to about 40°C at 45 cm depth and about 60°C at 5 cm. Pathogens do not survive these temperatures. The process of soil solarisation takes about four to six weeks. The length of the period is important for penetration of the heat in the soil.

7 International trade

Introduction

This chapter provides insight into the international trade of tomatoes in Europe. This is done with export data from the European export database (Eurostat). Unfortunately, this database does not include producer and consumer prices.

The Eurostat database contains quantities and values by exporting and importing country per month per year. Prices are calculated from these statistics. It should be noted that the statistics include export of imported tomatoes from third countries (re-export).

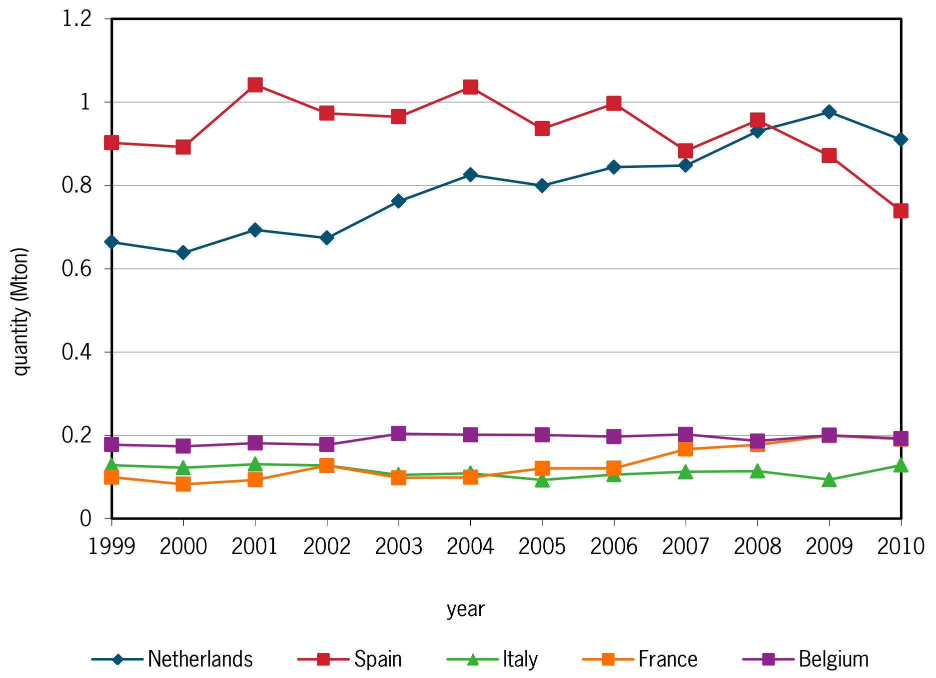
Germany is a major importing country for tomatoes in Europe. In Germany, strict residue restrictions are in force. Therefore, the exports to Germany have been studied in detail.

In this chapter, the Netherlands, Belgium, France, Spain and Italy are considered as exporting countries. First, the development of exports and the export calendar is analysed per country. Second, the export prices are discussed. Third, the imports of Germany are discussed.

Export per country

Figure 7.1 shows that Spain and the Netherlands export many tomatoes and that the exports from Belgium, France and Italy are significantly smaller. Exports from the Netherlands increased and from Spain decreased. Exports from France also increased, but this is caused by re-exports of Moroccan tomatoes. Approximately 80% of the tomato exports from Morocco go to France and these volumes increased in recent years.

Figure 7.1 **Export per country per year**



Export per country per month

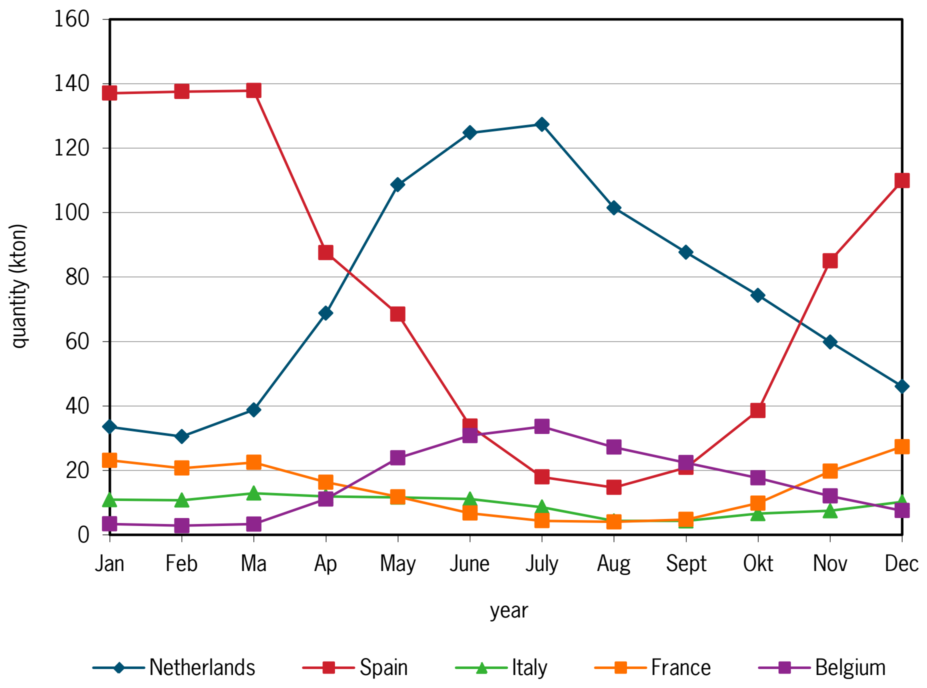
The export calendar in Figure 7.2 shows that the Netherlands exports tomatoes especially in and around the summer period and Spain in and around winter period. Belgium follows the calendar of the Netherlands, whereas France and Italy follow the calendar of Spain.

France has a larger area with summer production but still more tomatoes are exported in the winter period. This is because of the re-export of Moroccan tomatoes.

The information shows a clear difference in the export calendar between the northern and southern European countries. From the South the export takes place especially in the winter period and from the North the export is especially in summer period. This corresponds to the crop cycles (Chapter 2 to 6).

Exports from the Netherlands in winter are higher than the exports of Spain in summer. This is partly due to the re-exports of tomatoes by the Netherlands but also to the increasing part of the acreage of tomatoes in the Netherlands with artificial lighting. Artificial lighting enables the Netherlands to deliver tomatoes year round.

Figure 7.2 **Export per month per country 2006-2010**



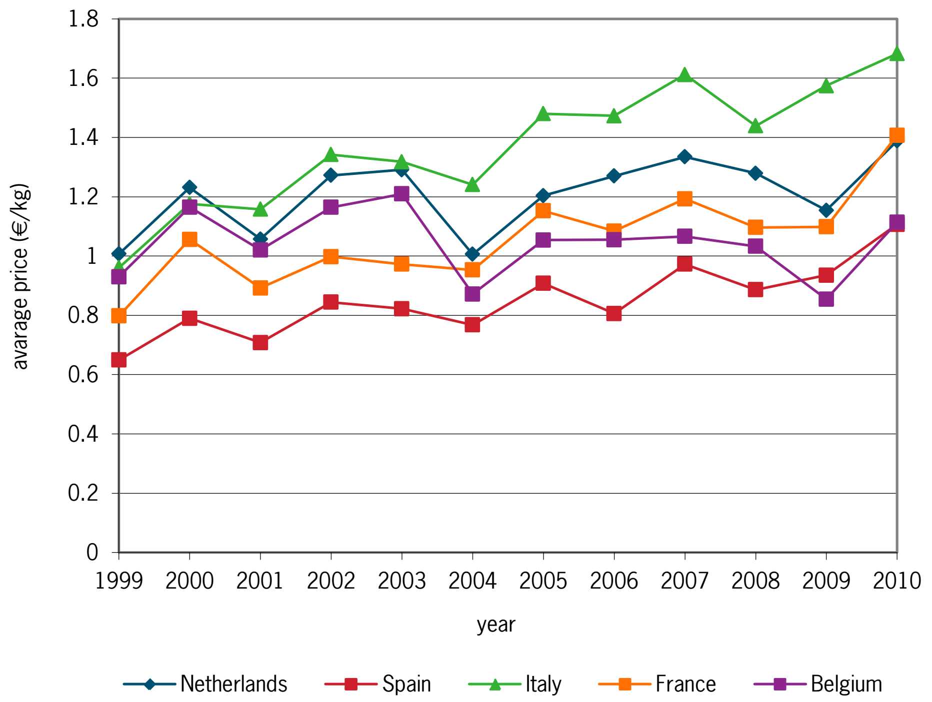
Export prices per country

Figure 7.3 shows that the export prices increased over the years until 2010. In 2011 this situation will be different as a consequence of the price crises in 2011 caused by the Enterohaemorrhagic Escherichia coli (EHEC bacterium).

In recent years, export prices from Italy are the highest and from Spain and Belgium the lowest, the Netherlands and France are in between. Price differences are related to the distinctive character of the products in terms of quality, durability, segmentation and product differentiation. Also, marketing concepts, supply and logistics play a role. Important aspects of quality are appearance (shape, colour and smoothness) and internal characteristics (taste and shelf life), food safety (residues of pesticides and pathogens) and the environmental impacts of production. In relation to crop protection, food safety and environmental impacts are important. This will be discussed in relation to the exports to Germany.

Italy exports especially small tomatoes and Spain and Belgium export more traditional types. The Netherlands and France grow more different types of tomatoes. In general prizes of small tomatoes are higher and prices of traditional tomato types are lower. This is one of the aspects of segmentation and product differentiation.

Figure 7.3 **Export price per country per year**



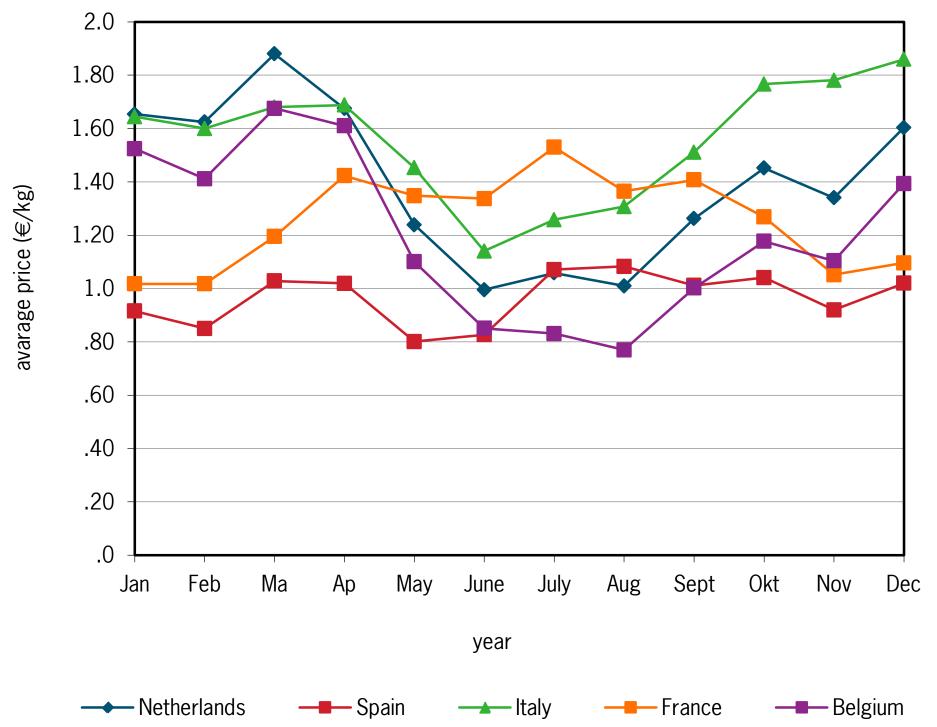
Export price per country per month

Figure 7.4 shows that the export prices of tomatoes are higher in winter period than in the summer period. Moreover, export prices of tomatoes from the Netherlands, Italy and Belgium are higher than for tomatoes from France and Spain in winter period. In summer, the differences between the countries are smaller and the export prices from France and Italy are higher.

A drop in prices can be witnessed at the end of winter/early spring in all countries (except France). The French exception is a consequence of cheaper re exports of Moroccan tomatoes by France in winter. The annual price trend explains why the use of technology (heating and CO_2 enrichment) in the greenhouses in the southern countries is of a limited size. In the southern countries, many tomatoes are grown without heating at the end of harvest in late winter/early spring. When heating were applied the quality of products as well as the growing period and the physical production would increase. However, the production growth achieved by heating is realised especially after the winter (Van der Velden et al., 2004a). That is to say in a period with dropping prices. Therefore, heating has not become common in greenhouses in the south. This argument does not apply to the use of technology for better ventilation of the greenhouses in relation to reducing diseases (Chapter 8).

For northern regions the annual trend operates in exactly the opposite direction. In the Netherlands, heating and CO_2 enrichment are normal in tomato crops in greenhouses. The harvest starts normally at the end of winter. The next step in technology application is artificial lighting. Through lighting the growing period and harvest starts earlier and more harvest is realized in winter. This production will be sold in periods with higher prices and therefore artificial lighting in greenhouse tomatoes is increasing in the Netherlands.

Figure 7.4	Export price per country per month 2006-2010



Exports to Germany by country

In Germany major retailers set restrictions to the residues. The restrictions are formulated in terms of maximum residue limits per active ingredient (MRL) and a maximum number of active ingredients (3-5). The latter criterion has a major impact on plant protection methods and entails that only a limited number of chemicals are allowed for use.

Figure 7.5 shows that the total exports from the five countries to Germany are characterised by some fluctuations over the years but there is no decreasing or increasing trend. Exports to Germany are dominated by the Netherlands and Spain but exports from the Netherlands are significantly higher than from Spain. Moreover, exports from the Netherlands increased and from Spain decreased. The exports from other countries are lower but the share of exports to Germany in total exports per country is important for each country (Table 7.1).

Figure 7.5 **Export to Germany by country and total**

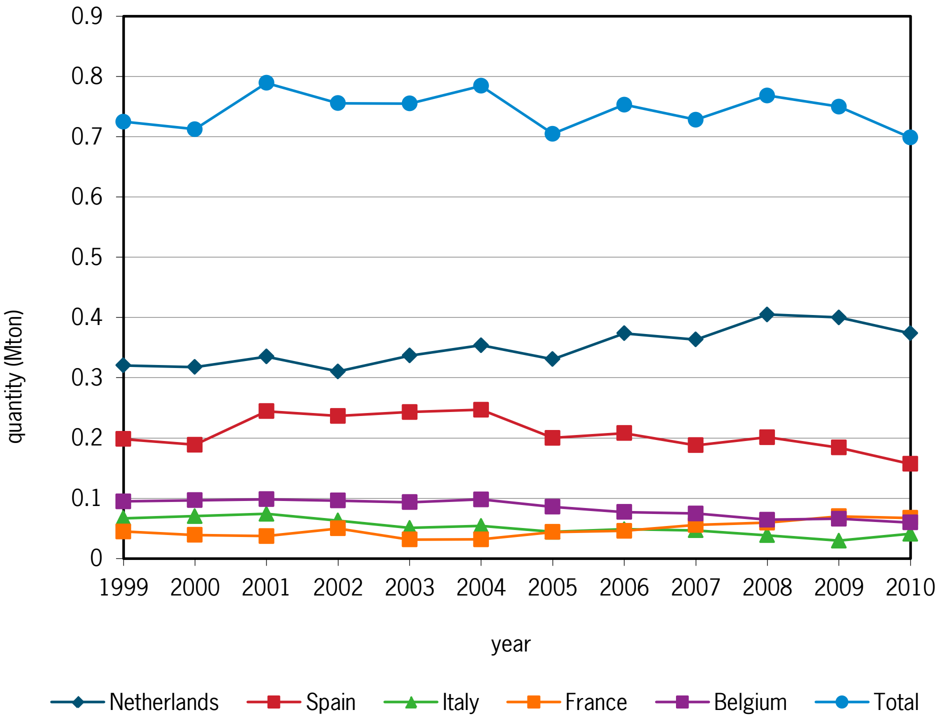


Table 7.1 **Share of export to Germany in total export by country in 2010 (%) a)**

Export country	**Share (%)**
Netherlands	41
Belgium	31
France	35
Spain	21
Italy	32

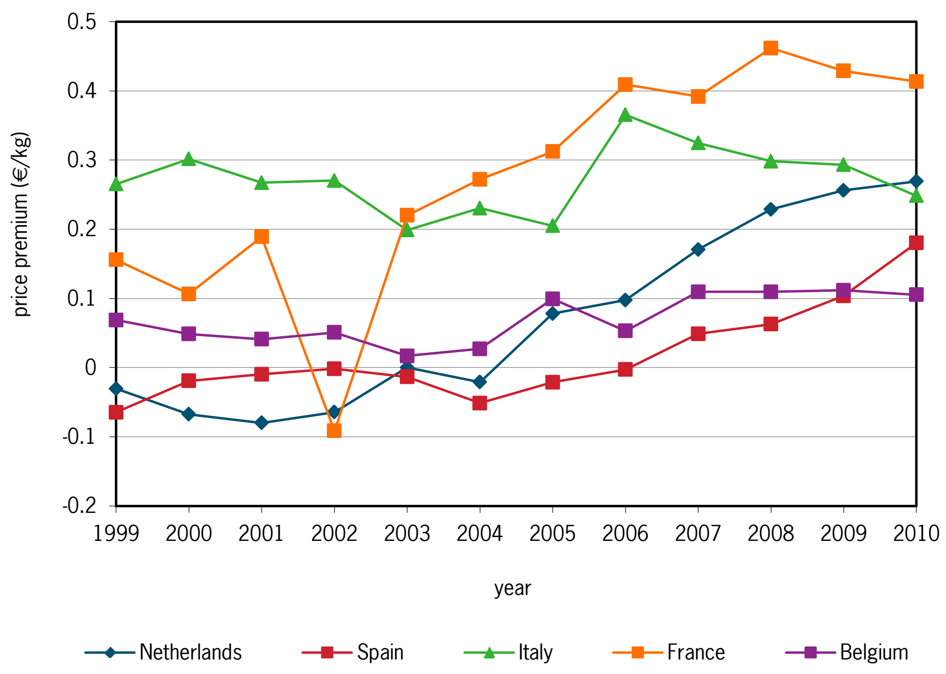
a) Including re export.

Export prices by country to Germany

Figure 7.6 presents the price premium for export to Germany. The price premium refers to the extent to which the export price to Germany is higher than the average price of the other exports from the individual countries. The figure shows that over the past 4-6 years a price premium is realised by the exports to Germany by all countries. At the beginning of this century this was not true for Spain and the Netherlands. The price premium runs from 10 to 40 €cents in 2010. France realised the highest price premium and Belgium the lowest. Spain is above Belgium and Italy and the Netherlands are above Spain.

The price premium is a combination of many aspects like appearance, internal characteristics, food safety and environmental impacts of production. IPM is a part of these aspects. Besides the fact that Germany is an important export country for all the countries in this study, because of the quantities, exports to Germany also achieved better prices. To realise these better prices the tomato exports must meet the market demands of Germany. These market demands include many aspects. One aspect is to meet the residue requirements of Germany in the cultivation of tomatoes in the exporting country. This means IPM does not results directly in higher prices for tomatoes. IPM is a licence to deliver in the market segments with higher prices and IPM prevents that the sales must take place in market segments with lower prices.

Figure 7.6	Price premium export to Germany by country



8 Synthesis

Introduction

The synthesis discusses successively:

- The gradient analysis;
- The major diseases and pests;
- The control methods;
- The economic aspects; and
- Future scenarios.

The gradient analysis is built from north to south (the Netherlands, Belgium, France, Spain and Italy) and shows the main differences between the tomato sectors of the five countries. The borderline between north and south is in the south-east of France. After the gradient analysis an overview of the major pests and diseases and the main control methods is shown. This part of the analysis is focused on the southern regions (Spain, Italy and southern France). In the economic aspects the costs and revenues of IPM are discussed. Finally, a scenario is outlined of a desirable future situation in the greenhouse tomato sectors in the southern regions in relation to reducing the use of chemicals for crop protection.

Gradient analysis

In the gradient analysis (Table 8.1) the Netherlands is divided in lighting and no lighting, France in heating and no heating, Spain in Murcia and Almería, and Italy in three main growing periods. For Belgium only heating is taken in consideration. The gradient analysis shows that from north to south, the cultivation and harvesting periods are shorter, except in the most southern part of Spain (Almería) and Italy (Sicily). In these latter regions the growing periods are a little bit longer because in these extremely southern regions it is a little bit warmer. What is also striking is that the main growing areas in all countries are located nearby the coast. This is probably due to the moderate climate and the higher sunlight levels near the coast but social aspect could also be important.

The crops in the south are more focused on harvesting in the winter period and in the north on the summer period. In the Netherlands, a part of the area with tomatoes is harvested in the winter period by the use of artificial lighting.

In the north more substrate or soilless cultivation is used and in the south cultivation takes place mainly in the soil. The greenhouses in the north are covered with glass and in the south with plastic. Heating, CO_2 enrichment and energy screens are standard in the north and not in the south. The climate control stands for ventilation in the south and for ventilation, heating, screen control and CO_2 enrichment in the north.

All these differences result in decreasing levels of physical production (kg/m^2) from north to south, except in the most southern part of Spain (Almería) and partly in Italy (Sicily). In these regions the physical production is somewhat higher because of the longer growing period.

The share of production that is exported is bigger in the north than in the south. This is also the case for the use of IPM.

Table 8.1 **Gradient analysis: major crop cycles and characteristics of greenhouse tomatoes per country in relation to IPM in 2010**

Feature	Unit	Country/region									
		Netherlands		Belgium	France		Spain		Italy		
		lighting	no lighting		heating	no heating	Murcia	Almería	winter/ spring	summer/ autumn	autumn/ winter
Acreage	ha	1,650		400-500	1,800		20,000		5,000		
Acreage	ha	250	1,400		1,100	700	2,000-3,000	8,000			
Crops per year		1	1	1	1	1-2	1-2	1	1-2		1
Growing period		Oct-Sept	Dec-Nov	Dec-Nov	Dec/Jan-Nov	Aug-Mar	Aug/Sept-Ma	Aug-Mar	Jan/Febr-Jun	Jul/Aug-Dec	Oct/Dec-Jun
Growing period	month	11	11	11	10	8	6	7	5	5	7
Harvest period		Dec-Sep	Ma-Nov	Ma-Nov	Ma-Nov	Oct-Ma	Nov-Ma	Nov-Ma	May-Jun/Jul	Sept-Dec	Feb-Jun
Harvest period	month	9	8	8	8	5	5	5	2	4	5
Type of tomatoes		mixed, much truss	mixed, much truss	much beef and truss	mixed, much truss	mixed, much traditional and loose	mixed, much traditional and loose		mixed, much little types, cherry and plum		
Substrate	%	>99	>99	95	much	limited	limited		limited		
Greenhouses		glass	glass	glass	much glass	plastic	plastic		plastic		
Ventilation		computer	computer	computer	much computer	hand	hand		hand		
Heating	% area	>99	>99	95	yes	no	incidental		incidental		
Export	%	>90	>90	80-90	<30		40-60		20-30		
Physical production	kg/m^2	30-60	30-60	30-60	40	15	10-14	12-16	7	7	12
IPM	% area	>99	>99	>99	60-70		± 70	± 50	<5		

Major pests and diseases

All occurring pests and diseases and possible biological agents in greenhouse tomatoes are listed in Appendix 2. The major pests and diseases in different countries are summarised in Table 8.2. In the table the pests (air), diseases (airborne), soil pathogens (soil-born diseases and pests) and viruses are distinguished as groups. The table and the backgrounds of the individual countries (Chapters 2-6) show the following:

- Pests and airborne diseases show strong similarities between the countries: sometimes it concerns different species;
- *Tuta absoluta* is a problem in the southern countries, although its incidence is starting to decrease after some years of coexisting;
- Thrips are more of a problem in the southern regions;
- The rust mite occurs in all countries and is probably a secondary pest and is likely related to the shift from broad spectrum to specific chemical agents;
- Viruses are a big problem in the south, especially the TYLCV transmitted by the white fly (*B. tabaci*) and the TSWV transmitted by different species of thrips;
- Airborne diseases are more of a problem in the south than in the north and this is partly due to the difference in technology application in relation to the greenhouses in relation to ventilation and heating;
- Soil pathogens (nematodes and soil-born diseases) are mainly a problem in Italy, this is probably due to cultivation in soil and the type of soil (clay).

Table 8.2 Main pests and diseases per country

	Netherlands	France	Spain	Italy
Viruses				
- TYLCV		+	+	+
- TSWV				+
- PepMV	(+)			
Pests				
- greenhouse whitefly (*Trialeurodes vaporariorum*)	+	(+)		+
- whitefly (*Bemisia tabaci*)		+	+	+
- tomato borer (*Tuta absoluta*)		+	+	+
- trips		+	+	+
- spider mite	+	+	+	+
- rust mite	+	+	+	+
- caterpillars	+	(+)	+	+
- aphids	+	(+)		
Diseases; airborne				
- *Botrytis*	+	+	+	+
- downy mildew	+	(+)		
- powdery mildew (*Oidium*)		+	+	+
- *Cladosporium*		+		+
Soli pathogens (diseases; soil born and nematodes)				
- *Phytophthora*		+	+	+
- *Fusarium*				+
- *Pythium*				+
- nematodes		(+)	(+)	+

Control methods
The main control methods used to control pests and diseases in different countries are summarised in Table 8.3. In the table viruses, pests, airborne diseases, soil pathogens (soil-born diseases and nematodes) are distinguished as groups. Subsequently, the most important control methods are given. The overview and backgrounds of the individual countries (Chapters 2-6) show the following:

- In the southern regions the viruses are controlled with nets in the ventilation openings of the greenhouses in combination with the control of whiteflies and thrips and tolerance of the tomato plants;
- Biological pest control agents are important in all countries, except in Italy;
- In addition to biological pest control agents also mass traps to catch the pests are used, and in the southern countries the use of nets in the ventilation openings of the greenhouses is widely applied;
- Due to the biological control of pests and the use of bumblebees for pollination the use of broad spectrum chemicals has shifted to specific chemicals;
- In Spain in particular, the predator *Nesidiocoris tenuis* is used for pest control. *Nesidiocoris tenuis* occurs freely in nature. Large populations of *Nesidiocoris tenuis* may also be a pest for the tomato crop. The tomato growers in France and the Netherlands do not want to use this predator;
- An adequate predator for the secondary pest rust mite is not available;
- Biological control of diseases is not used due to the unavailability of antagonists;
- In the control of airborne diseases ventilation of the greenhouses for moisture plays an important role. The use of technologies such as automatic climate control and heating in the north reduce the problem. In the southern regions, the tomatoes are hardly heated and this is not likely to change as a result of lower tomato prices in the periods with extra production by heating (Chapter 7). In the south important improvements are achieved in relation to the ventilation of the greenhouses but the nets in the openings reduce the ventilation;
- In the southern regions the control of soil pathogens takes mainly place with chemical agents and also with the use of tolerant rootstocks (Spain) and on a smaller scale with substrates and soil solarisation. In the north substrates are used;
- In the fight against pests and diseases more attention to soil quality and plant health in relation to the resilience of the crop was demanded by stakeholders in all countries. In the north, this includes the influence of the temperature in the greenhouses on the crop. Higher temperatures are associated with thinner plants.

Economic aspects
With respect to the economic aspects of IPM, there are indications from Spain that the biological control of pests is cheaper than chemical control. This corresponds to the development of the average costs of plant protection in Almería (Chapter 5).

In Italy this is more difficult, which is related to the shorter growing periods. Predators are released especially at the beginning of the cultivation, and these initial costs have to be divided over a shorter growing period and also over a lower physical production. The same problem occurs with grafting (root stocks), which results in more expensive plants, and with substrate cultivation which results in higher costs per m^2.

Information for a detailed cost-benefit analysis is not available. Therefore, a more qualitative approach has been chosen.

Table 8.4 shows the average costs for crop protection in Almería. This is around €0.45 per m^2 in 2005 and around €0.35 per m^2 in 2010. This cost reduction of approximately €0.10 per m^2 is associated with the use of IPM. This means that IPM has a major impact on the costs for plant protection but the impact on the total costs (about €7/m^2) is limited.

Besides the costs, we could also look at the revenues. Revenues (€/m^2) are determined by the physical production (kg/m^2) and the tomato price (€/m^2).

Table 8.3	Main control methods of pests and diseases per country			
	Netherlands	**France**	**Spain**	**Italy**
Viruses				
- chemical (pests)	-	+	+	+
- nets (pests)	-	(+)	+	+
- tolerance	-	+	+	+
Pests				
- chemical	(+)	+	+	+
- nets	-	(+)	+	+
- trapping	+	+	+	+
- biological	+	+	+	(+)
- tolerance	-	-	-	-
Diseases airborne				
- chemical	+	+	+	+
- ventilation	+	+	+	+
- heating	+	(+)	-	-
- biological	-	-	-	-
- tolerance	-	-	-	-
Soil pathogens				
- chemical	-	+	+	+
- rootstock (tolerance)	-	(+)	+	(+)
- substrate	+	+	(+)	(+)
- steam (substrate)	(+)	-	-	-
- solarisation	-	-	(+)	(+)
- tolerance	-	-	-	-

There are several indications that less spraying has a positive effect on production. It is claimed by the stakeholders and in professional journals that one-time spraying decreases crop growth by one day because of the phytotoxic effect on the crop. Table 8.5 shows variants of +2, +4 and +8% increase of production.

Chapter 7 has shown that IPM gives access to market segments with higher prices. Table 8.5 shows variants of price effects of +2, +4 and +8%.

Combinations of a higher production and a better price are also included in Table 8.5.

The overall picture from Tables 8.4 and 8.5 shows that improvements in revenues have a larger effect than reduction in costs. The economic opportunities for IPM should therefore mainly come from the revenues. Perhaps marketing concepts could be developed or further developed in the future to achieve this. However, a knowledge gap in this area exists.

Table 8.4	Average costs of crop protection in Almería and maximum changes (€/m^2)	
	2005	**2010**
Chemical	a)	0.25
Biological	a)	0.10
Total	0,45	0.35
Δ		- 0.10

a) Not available.

Table 8.5	Calculated effects of physical production and farm gate prices on revenues; long crop cycle tomatoes in Spain				
		Current situation	Calculated effects		
Increase physical production					
Physical production	kg/m²	14	14.28 (+2%)	14.56 (+4%)	15.16 (+8%)
Price	€/kg	0.50	0.50	0.50	0.50
Revenues	€/m²	7.00	7.14	7.28	7.56
Effect on revenues	€/m²		+ 0.14	+ 0.28	+ 0.56
Market segment with higher prices					
Physical production	kg/m²	14	14	14	14
Price	€/kg	0.50	0.51 (+2%)	0.52 (+4%)	0.54 (+8%)
Revenues	€/m²	7.00	7.14	7.28	7.56
Effect on revenues	€/m²		+ 0.14	+ 0.28	+ 0.56
Combination					
Physical production	kg/m²	14	14.28 (+2%)	14.56 (+4%)	15.16 (+8%)
Price	€/kg	0.50	0.51 (+2%)	0.52 (+4%)	0.54 (+8%)
Revenues	€/m²	7.00	7.28	7.57	8.16
Effect on revenues	€/m²		+ 0.28	+ 0.57	+ 1.16

Future scenarios

The previous section about economic aspects has shown that the economic opportunities for IPM should mostly come from the price premium of the tomatoes. Chapter 7 showed that meeting the stringent German residue requirements is of great importance. For the future it is expected that these residue restrictions will become even more stringent, not only in Germany. Achieving further reductions in the use of chemicals in the southern regions is pivotal to target the stricter residue demands on the market. This is outlined in three future scenarios.

Control of pests with IPM is technically largely possible. The biggest challenge in relation to IPM are the diseases (airborne and soil born) and nematodes. Soil solarisation, root stocks and substrate are important options for controlling soil-born pathogens (diseases and nematodes). The future scenarios are primarily focused on the diseases (air born). For controlling airborne diseases more solutions are possible. Plastic greenhouses in the south are equipped with nets to exclude the pests and the infection of viruses by the pests. However, these nets decrease the ventilation of the greenhouses and increase the problems with air borne diseases. In a situation of removing the nets the pests and viruses became a problem again. Starting from this situation three scenarios were developed.

The scenarios include two scenarios with nets and one scenario without nets. The two scenarios with nets include a technological scenario and a biological scenario. The scenario without nets is a biological scenario. The scenarios are explained below and visualized in Table 8.6.

Table 8.6	Possible future scenarios		
Characteristics	**Scenario**		
	with nets		**without nets**
	technological	**biological**	**biological**
Improvement of ventilation; low tech	+		
Tolerance of diseases airborne		+	
Antagonists of diseases airborne		+	
Tolerance of pests			+
Tolerance of viruses			+
Resilience of the crop	+	+	+

1. Technological scenario with nets
   In the technical scenario with nets the technical improvement of the ventilation in the greenhouse is characteristic. These technical improvements have to be low tech because of the limited possibilities for cost recovery from the low physical production and low revenues per m^2 in greenhouse tomatoes in the south of Europe (Table 8.5). The dropping tomato prices after winter (Chapter 7) further restrict the possibilities for cost recovery. This also acts as a barrier for growers to invest in heating. Because of the low tech improvements a combination with the resilience of the crop will be necessary in this scenario.

2. Biological scenario with nets
   In the biological scenario with nets the development of tomato varieties with tolerance against diseases and the development of antagonists against diseases is characteristic. Because a 100% tolerance is unrealistic the resilience of the crop will be necessary in this scenario.

3. Biological scenario without nets
   The scenario without nets is also a biological scenario. In this scenario the development of tomato varieties with tolerance against pests and viruses is characteristic. Because a 100% tolerance is unrealistic the resilience of the crop will be also important in this scenario.

The final question is which scenario will be the most promising for the future? Scenario 3 is difficult because it is contradictory to the historical development. This means scenario 1 and 2 have better prospects to be realised. Because of the low costs requirements of scenario 1 a combination of scenario 1 and 2 seems obvious.

9 Conclusions and recommendations

The conclusions and recommendations focus on the residue restrictions on the international market for tomatoes. These restrictions are key to the objectives of PURE work package 7, which is to reduce the use of chemicals for crop protection in the production areas in southern Europe (Spain, Italy and southern France), and the research in task 3a, 3b and 4 of Work Package 7 of the PURE programme.

The study results in the following conclusions and recommendations.

Revenues and costs

- For IPM increasing revenues is more promising than reducing costs. Higher revenues mean higher production and especially price premium.
- Research should focus on production of quality tomatoes for exports and especially meeting the German residue restrictions because of the price premium.
- For residue restrictions, both the maximum number of different chemicals and the residue levels are important.
- Consequently, the experiments (task 3) and the ex post assessment (task 4) should focus on IPM strategies by which the residue restrictions can be achieved.

Diseases

- The biggest challenge in relation to IPM are the diseases (airborne and soil born) and nematodes.
- Research should focus on non-chemical alternatives: soil solarisation, root stocks and substrate for controlling soil-born pathogens (diseases and nematodes); the economic perspectives of these alternatives are best in the long winter crops.
- Research should focus on greenhouses with better ventilation options and improvements in this area for the control of airborne diseases.
- The development of antagonists and tolerance of the crop is desired for disease control.

Pests

- Control of pests with IPM is technically largely possible.
- The economic perspectives of pest control with IPM are best in the long winter crops.
- *Nesidiocoris tenuis* is not only a predator but also a pest and requires future attention.
- Research will also have to focus on mites as secondary pests.

Finally, a better understanding of the potential of plant health and soil quality as a means to reduce the dependency of chemical pests control is needed.

Literature

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Appendix 1

Checklist interviews practical experts task 1 and 2

A. General project information

- PURE Programme; European Programme; IPM Solutions; more crops
- WP 7 IPM Solutions for protected vegetables - Tomatoes in greenhouses (Project leader INRA-France)
- Overall objective: To design more robust IPM solutions to implement not only in high tech greenhouse systems.
  - → Focus on Spain, Italy and France
  - → Four tasks
    - Task 1; Greenhouse technological packages and tactic packages design with stakeholders (Task leader IVIA Spain)
    - Task 2; Ex-ante assessment including stakeholders' input (Task leader LEI Wageningen UR, The Netherlands)
    - Task 3; IPM solutions testing
      - 3a; On Station experimentation of candidate IPM solutions (Task leader INRA France)
      - 3b; On farm test of IPM solutions and dialogue with stakeholders (Task leader IVIA Spain)
    - Task 4; Ex-post assessment including stakeholders' input (Task leader CNR Italy)
  - → Stakeholders → practical experts
  - → Task 1 and 2; Talks/interviews practical experts
    - situation 2010/2011
    - developments during the years (before 2010 and after 2010/trends)
    - basic documents per country; Spain, Italy and France/additions/improvements

- What experience does the expert have with IPM ?

B. Glasshouse industry/sector structure

- Area greenhouse tomatoes per country
- Area per region per country → regions; marking on map
- Type of tomatoes per country and region
- Growing periods (planting, start and end harvest) per region and type of tomato

C. Technology

- Types of greenhouse per …
- Climate control per …
- Heating per …
- CO^2-enrichment per ...
- Moistening per ...
- Dehumidifying per ...
- Cooling per …
- Type of soil/substrate per …

D. Sale/Market

Home land/export <u>per</u> country, region, type of tomatoes and growing period

E. IPM

Pests and diseases
- common pests and diseases → list basic document per country
- IPM possibilities/solutions (existing and new) → list basic document per country
- bottlenecks (no IPM solutions available) → list basic document per country

Development paths IPM; 3 steps
- efficiency (dosage, spray techniques)
- substitution (broad spectrum chemicals by specific chemicals or predators)
- re design (species, hygiene at the holdings, greenhouse types, climate control)

What are the developments in IPM for tomatoes (history, actual situation, future)
- penetration of the use of IPM per … (acreage; %)
- opportunities
- problems/constraints
    - available predators
    - adaptation by growers
        - technical
        - economic
        - environment
        - physical/infection
        - social/contacts/advises
    - real bottlenecks
        - short term
        - long term

Relations between
- types of tomatoes and sensibility for pests and diseases (resistant/tollerance)
- pests and diseases and the use of technology (type of greenhouses and climate control)
- IPM and the use of technology

Which chemicals are used in the situation with and without IPM
- spray equipment
- treatments/calendar/quantities/active ingredient
- available data/groups of holding

F. Economic: costs and benefits IPM (partial gross margin)

Required information:
- relations between IPM solutions and costs
- extra costs IPM (predators, other chemicals, labour, …)
- decreasing costs IPM; investments (spray equipment), chemicals, labour, …)
- relations between IPM solutions and benefits
- delta turnover; production and price (delta between with and without IPM)
- delta production (kg/m^2); crop damage (production and quality) by diseases and by spraying, …
- delta prices (€/kg); reward/price premium by IPM ?, ...
- …

G. Environment ?

Required information:

- spray schedules (without and with IPM) (also needed for costs and benefits)
- → chemical products, prices, quantities en active ingredient
- active ingredients/toxicity/dissemination/evaporation → information available ?
- chemicals working reach (wide/specific)
- …

H. Other stakeholders/practical experts → per country

- Names of people who know more about subjects mentioned in the list
- Spain, Italy and France

I. Information for stakeholders/practical experts

- Export data tomatoes per country

Appendix 2

Pests and diseases and possible biological agents in greenhouse tomatoes in southern Europe

Pests/diseases	**Non-chemical (biological) solution (name natural enemy)**
Pests	
- whitefly (Hemiptera: Aleurodidae) *Bemisia tabaci* (Gennadius)	- *Nesidiocoris tenuis* Reuter (Hemiptera: Miridae) - *Macrolophus pygmaeus* (Rambur) (Hemiptera: Miridae) - *Eretmocerus mundus* Mercet (Hymenoptera: Aphelinidae) - *Eretmocerus eremicus* Rose & Zolnerovich (Hymenoptera: Aphelinidae) - *Encarsia formosa* (Gaham) (Hymenoptera: Aphelinidae) - *Beauveria bassiana* - *Verticillium lecanii*
- whitefly (Hemiptera: Aleurodidae) *Trialeurodes vaporariorum* Westwood	- *Nesidiocoris tenuis* Reuter (Hemiptera: Miridae) - *Macrolophus pygmaeus* (Rambur) (Hemiptera: Miridae) - *Eretmocerus eremicus* Rose & Zolnerovich (Hymenoptera: Aphelinidae) - *Encarsia formosa* (Gaham) (Hymenoptera: Aphelinidae) - *Beauveria bassiana* - *Verticillium lecanii*
- thrips (Thysanoptera: Thripinae) *Frankliniella occidentalis* (Pergande)	- *Nesidiocoris tenuis* Reuter (Hemiptera: Miridae) - *Macrolophus pygmaeus* (Rambur) (Hemiptera: Miridae) - *Amblyseius cucumeris* (Oudemans) (Acari: Phytoseiidae) - *Beauveria bassiana* - *Hypoaspis miles* (Berlese) (Acari: Laelapidae) - *Hypoaspis aculeifer* (Canestrini) (Acari: Laelapidae)
- leaf miners (Diptera: Agromyzidae) *Liriomyza trifolii* (Burgess) *L. bryoniae* (Spencer) *L. huidobrensis* (Blandchar)	- *Diglyphus isaea* (Walker) (Hymenoptera: Eulophidae) - *Dacnusa sibirica* Telenga (Hymenoptera: Braconidae) - *Nesidiocoris tenuis* Reuter (Hemiptera: Miridae) - *Macrolophus pygmaeus* (Rambur) (Hemiptera: Miridae)
- tomato leaf miner *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae)	- *Nesidiocoris tenuis* Reuter (Hemiptera: Miridae) - *Macrolophus pygmaeus* (Rambur) (Hemiptera: Miridae) - *Trichogramma achaeae* Nagaraja and Nagarkatti (Hymenoptera: Trichogrammatidae) - *Necremnus artynes* (Walker) (Hymenoptera: Eulophidae) - *Bacillus thuringiensis*
- caterpillars (Lepidoptera: Noctuidae) *Helicoverpa armigera* Hübner *Chrysodeixes chalcites* (Esper) *Autographa gamma* L. *Spodoptera littoralis* (Boisduval) *Spodoptera exigua* (Hübner)	- *Nesidiocoris tenuis* Reuter (Hemiptera: Miridae) - *Macrolophus pygmaeus* (Rambur) (Hemiptera: Miridae) - *Bacillus thuringiensis*
- caterpillar *Agrotis segetum* Denis & Schiffermüller (Lepidoptera: Noctuidae)	
- aphids (Hemiptera: Aphididae) *Myzus persicae* Sulzer	- *Aphidoletes aphidimyza* (Rondani) (Diptera: Cecidomyiidae) - *Aphidius matricariae* - *Beauveria bassiana* - *Episyrphus balteatus* DeGeer (Diptera: Syrphidae)

Pests/diseases	Non-chemical (biological) solution (name natural enemy)
	- *Adalia bipunctata* Linneo (Coleoptera: Coccinelidae) - *Aphidius colemani* (Haliday) (Hymenoptera: Aphidiidae)
- aphids (Hemiptera: Aphididae) *Macrosiphum euphorbiae* Thomas *Aulacorthum solanii* (Kaltenbach)	- *Aphelinus abdominalis* (Dalman) - *Aphidius ervi* (Haliday) (Hymenoptera: Aphidiidae) - *Aphidoletes aphidimyza* (Rondani) (Diptera: Cecidomyiidae) - *Episyrphus balteatus* DeGeer (Diptera: Syrphidae) - *Adalia bipunctata* Linneo (Coleoptera: Coccinelidae) - *Beauveria bassiana*
- spider mites (Acari: Tetranychidae) *Tetranychus urticae* Koch	- *Feltiella acarisuga* (Vallot) (Diptera: Cecidomyiidae) - *Phytoseiulus persimilis* (Athias-Henriot) (Acari: Phytoseidae) T strain - *Amplyseius andersoni* Chant (Acari: Phytoseidae) - *Nesidiocoris tenuis* Reuter (Hemiptera: Miridae) - *Macrolophus pygmaeus* (Rambur) (Hemiptera: Miridae) - *Beauveria bassiana*
- spider mites *Tetranychus evansi* Baker & Pritchard	- *Feltiella acarisuga* (Vallot) (Diptera: Cecidomyiidae) - *Amplyseius andersoni* Chant (Acari: Phytoseidae) - *Nesidiocoris tenuis* Reuter (Hemiptera: Miridae) - *Macrolophus pygmaeus* (Rambur) (Hemiptera: Miridae) - *Beauveria bassiana*
- russet mite *Aculops lycopersici* (Masse)	- *Amplyseius andersoni* Chant (Acari: Phytoseidae)
Airborne diseases	
- *Botrytis cinerea*	- *Trichoderma harzianum* - *Bacillus subtillis*
- *Leveillula taurica*	
- *Phytophthora infestans*	
- *Alternaria solani*	
- *Collethotrichum coccodes*	
- *Fulvia fulva*	
- *Oidium neolycopersici*	- *Ampelomyces quisqualis* strain AQ10
- *Septoria lycopersici*	- *Trichoderma harzianum*
Soil-born diseases	
- *Phytophthora nicotianeae*	
- *Rhizoctonia solani*	- *Trichoderma harzianum* - *Streptomyces griseoviridis Strain K61* - mycorrhiza
- *Sclerotinia sclerotiorum*	- *Trichoderma harzianum* - *Coniothyrium minitans*
- *Pythium* spp.	- *Trichoderma harzanianum* - *Streptomyces griseoviridis Strain K61* - mycorrhiza
- *Fusarium oxysporum f.* sp. *Radices lycopersici*	- *Trichoderma harzianum* - *Streptomyces griseoviridis Strain K61*
- *Verticillium albo-atrum and Verticillium dahliae*	- *Streptomyces griseoviridis Strain K61*
- *Sclerotium rolfsii*	- *Trichoderma harzianum* - *Coniothyrium minitans*

Pests/diseases	Non-chemical (biological) solution (name natural enemy)
Virus	
- TYLCV and TYLCSV	- Control of the vector *Bemisia tabaci*
- ToCV and TICV	- Control of the vectors *Trialeurodes vaporariorum* and *Bemisia tabaci*
- TSWV	- Control of the vector *Frankliniella occidentalis*
- PepMV	
- ToMV	
- Torrao	
Bacteria	
- *Clavibacter michiganensis* subsp. *michiganensis*	
- *Pseudomonas corrugate*	
- *Xanthomonas campestris* pv. *vesicatoria*	
- *Pseudomonas syringae* pv. *tomato*	
Nematodes	
- Root-knot nematodes *Meloidogyne* spp.	- Paecilomyces *lilacinus* strain 251

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