ENDURE

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Survey and analysis of "the state of art of scab, brown spot and codling moth prevention and control strategies"

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PP Restricted to other programme participants (including the Commission Services)	
RE Restricted to a group specified by the consortium (including the Commission Services)	
CO Confidential, only for members of the consortium (including the Commission Services)	

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Glossary

Apple scab: A disease of apple caused by the fungus *Venturia inaequalis*. A related fungus *Venturia pirina* causes pear scab. Apple scab is one of the most important diseases of apple in the world where apple production takes place. The symptoms are dark brownish lesions on leaves and fruits and early leaf fall.

Brown spot of pear: A disease of pear caused by the fungus *Stemphylium vesicarium*. The overwintering sexual stage is *Pleospora allii*. The symptoms are rotting of fruits already in the orchard before harvest.

Codling moth: A pest of mainly apple but also pear caused by the tortricid moth *Cydia pomonella*. It is the most important pest of apple all over the world.

Integrated control method: A method to control a pest or a disease which takes in consideration effects on environment and or natural control.

Toolbox: A set of integrated control methods forming the strategy of pest and disease control in a region. Toolboxes can be different in different regions or countries.

Tools: Elements of an integrated control method.

Summary

In this study information is collected on the state of art of integrated control methods used in the major pome fruit production regions of Europe. The regions included in this study are: Lake Constance (Germany and Switzerland), Cataluña (Spain), Emilia Romagna, South Tirol and Trentino (Italy), Rhone Valley (France), Belgium, Netherlands and Sweden. Three problems of pome fruit were studied. These were codling moth (*Cydia pomonella*), brown spot of pear (*Stemphylium vesicarium*) and apple scab (*Venturia inaequalis*). Analyses of the collected information provide the following conclusions.

Conclusions

From the analyses of the collected information the following conclusions are drawn.

- Knowledge on integrated control methods is in generally quickly and well spread in the European countries involved in this study.
- Spreading of knowledge is done by governmental or private organisations, including those of growers and retailers, often by extension services.
- Information on timing of pesticide applications based on decision support systems is often done with modern communication technologies, like SMS and e-mail.
- Toolboxes contain the same tools for integrated control of the three pests / diseases from this study in all regions covered in this study. Hence, there are no differences between northern or southern regions within Europe in this aspect.
- Even the importance of the different tools is very much similar in northern and southern regions in Europe.
- There are only small differences in the percentage of growers using the different tools for integrated control between European fruit producing regions.
- It is unknown if newer European member states have access to up to date information on tools for integrated control.
- Newer European member states could profit existing knowledge through Endure channels of communication.
- There are clear bottlenecks in adopting newer tools of integrated control. For example the major bottleneck for growing less susceptible of resistant cultivars is that these have less economic value.
- Bottlenecks for implementation of new integrated control measures often have multiple backgrounds, especially technical and economical reasons.

Introduction

Integrated control of pome fruit pests and diseases is well established in Europe. Corner stones of integrated pome fruit production are the biological control of spider mites, like *Panonychus ulmi* with predatory mite *Typhlodromus pyri* and the use of decision support systems for the control of apple scab caused by *Venturia inaequalis*. Practical growers choose their chemical pesticide products based on the criterion, that they will not affect predatory mite populations. Integrated control, however, is not a steady state. Many research groups continuously work on new elements of integrated control in pome fruit. They deliver for example advanced warning systems, or new environment friendly control strategies. A recent overview of active research groups is given in Endure Deliverable 1.7 “Survey of ongoing research and facilities”. These new scientific possibilities change practice. But also the release of new groups of pesticides, and the opposite, the banning of many old pesticides, influence practice and integrated control in a substantial way.

New developed scientific methods of integrated control in pome fruit has to find its way into practice. Most often new developments are first introduced into practice locally by the researcher him self. Sometimes directly for a whole country. Subsequently, advisors have to be convinced of the advantages of the new method, and they will start promoting it. Further introduction is much dependent on integrating the new method within the total management of the orchard system in practice. There are differences in orchard management systems over Europe. New developments of integrated control measure can be found in scientific literature and congress proceedings. However, it is not clear which integrated control measures are really used in practice.

Therefore, the purpose of this deliverable (DR1.8) is to make an inventory of integrated control measures used in practice in different European pome fruit production regions. From this survey an analysis is made, which tools of integrated control methods could be transplanted to from one pome fruit production region to others. This is the purpose of deliverable DR1.9.

In this study, the integrated control methods are collected for apple scab (*Venturia inaequalis*), brown spot on pear (*Stemphylium vesicarium*) and for codling moth (*Cydia pomonella*) because these are the diseases and one pest responsible for a substantial part of pesticides used to reduce risks of severe losses in pome fruit production in Europe. Consequently, a further implementation of integrated control measures for these pests will reduce substantially pesticide use in pome fruit production.

1 Material and methods

1.1 *Data collection*

During the meeting of members of the Endure Case Study Pomefruit at Avignon, France, 26-27 April 2007, tasks were split among Endure participants to collect all the information for the two diseases, apple scab caused by *Venturia inaequalis*, and brow spot of pear caused by *Stemphylium vesicarium* and pest codling moth caused by *Cydia pomonella*. K. Paaske (Aarhus University) was leading the collection of this information on apple scab and specifically assisted by A. Patocchi (Agrocope Wädenswill) and L. Parisi (INRA). B. Heijne (Wageningen UR/PPO) was leading the collection of this information on brown spot of pear and specifically assisted by J. Avilla (University Lerida UdL). D. Cassado and J. Avilla (University Lerida UdL) were leading the collection of this information on codling moth and specifically assisted by J. Samietz (Agrocope Wädenswill) and B. Sauphanor (INRA). B. Heijne (WUR/PPO) assembled all the information which is presented in this deliverable.

1.1.1 Procedure

A questionnaire was set-up originally for codling moth and adapted for apple scab and brown spot of pear. The questionnaires in English were send by e-mail to scientist colleagues as listed in Deliverable DR1.7 and to plant protection officers all over Europe. These were both participants within the Endure project as well as to non-participants of Endure. Personal interviews were carried out in some cases. The results of the collected information was discussed and analysed in a meeting of participants of the Endure Case Study Pomefruit at Lleida, Spain, 24-25 April 2008. The result of the collected information and the analyses is presented is this combined Deliverable DR1.8 and DR1.9.

1.1.2 Regions

Information on integrated control methods was collected from different important European pome fruit growing regions. These were determined in agreement with partners of Work Package RA3 of the Endure project, during the meeting at Tänikon, Switzerland, 3 May 2007. The regions were: Lake Constance both the German and the Swiss side, Emilia Romagna (Italy), The Netherlands, Rhone Valley (France) and Catalonia (Spain). Additionally information is collected from Belgium, Trentino (Italy), South Tyrol (Italy) and Sweden.

1.1.3 Content of the questionnaire

A questionnaire was set-up specific for codling moth, for apple scab and for brown spot on pear. General approach was to collect information on specific tools for integrated control strategies. These tools were:

- cultural methods and orchard management
- use of pesticides
- use of decision support systems
- use of non-chemical or environmentally friendly products
- sanitation
- use of resistant cultivars

Of course the questions were specified according to the relevant pest or disease. For each of these tools it was asked if

- the strategy was ready or still under development
- what percentage of growers is using it in practice
- how the perspectives were for (further) implementation into practice

- if obstacles for further implementation could be identified, specified for labour, economic or practical reasons.

1.2 *Analyses of the collected information*

The collected information is presented firstly in a descriptive way for each of the diseases and the pest. If possible, the collected information was summarised in tables per region and integrated control method. However, this was not possible for all diseases. The purpose of the presentation in tables was, to facilitate drawing conclusions about identifying gaps in use of integrated control methods and search for possibilities for transplanting integrated control methods from one region to another.

2 Survey of the state of the art of codling moth integrated control strategies

2.1 *Questionnaire and regions covered*

The questionnaires were very similar for codling moth, brown spot of pear and apple scab (see Annex 1 for the apple scab questionnaire). The questionnaire was sent to scientist and/or plant protection officers from 9 European apple and pear growing areas (Table 2.1.1). Personal interviews were also carried out in some cases. The selected regions cover about 75.000 ha of apple orchards and 53.000 ha of pear ones. They are representatives of Northern and Southern European climates, and active Integrated Pest Management programs have been developed and are currently applied in them. The regions are: Emilia Romagna, Trentino and South Tyrol (all three in Italy), Lake Constance (Germany), Lake Constance (Switzerland), The Netherlands, Sweden, Rhône Valley (France) and Lleida (Spain).

Table 2.1.1 Information about the regions covered by the answers to the questionnaires relating to codling moth

Region (Country)	Contact person	Institution	Control strategy	Orchard Surface (ha)
1. Emilia Romagna (Italy)	Alda Butturini & Mauro Boselli	Plant Protection Service - Emilia Romagna Region	Integrated Pest Management	Apple: 6.045 Pear: 26.290
2. Trentino (Italy)	Claudio Ioriatti & Luisa Mattedi	Agricultural Institute of San Michele all'Adige	Integrated Pest Management	Apple: 12.500 Pear: 300
3. South Tyrol (Italy)	Roland Zelger	Research Centre Laimburg	Integrated Pest Management	Apple: 18.000
4. Lake Constance (Germany)	Peter Triloff & Martin Trautmann	Extension Service	Integrated Pest Management	Apple: 7.500 Pear: 500
5. Lake Constance (Switzerland)	Richard Hollenstein & Urs Müller	Extension Service	Integrated Pest Management	Apple: 1.600
6. Netherlands	Herman Helsen	Wageningen UR / Applied Plant Research	Conventional	Apple: 9.500 Pear: 7.000
7. Sweden	Christer Tornéus	Plant protection Centre. Swedish Board of Agriculture	Conventional	Apple: 1.700 Pear: 200
8. Rhône Valley (France)	Jean François Toubon	INRA Avignon	Integrated Pest Management	Apple: 8.000 Pear: 3.500
9. Lleida (Spain)	Ramon Torà	Plant Protection Service – Catalonia Region	Integrated Pest Management	Apple: 9.300 Pear: 14.000

2.2 *Description of the whole strategy per region*

2.2.1 Emilia Romagna (IT)

Mostly pears are growing in Emilia Romagna (26.290 ha of pear orchards *vs.* 6.045 ha of apple orchards). Integrated Pest Management is carried out in about 10.000 ha of pear orchards and 1.700 ha of apple orchards. IPM guidelines for apples and pears are available for the growers and they also strongly influence conventional farmer decisions. A weekly bulletin is produced in each of the 9 Provinces by the local technicians under the co-ordination of the Regional Plant Protection Service and it provides information to the growers (conventional farmers included).

Codling moth has three generations per year, but the third is partial, as up to 50 % of the larvae of the 2nd generation can diapause. Population monitoring is carried out mainly with pheromone traps (the installation of at least two traps per farm is recommended), and fruit damage during season. Both variables are used to decide on pesticide application. Egg laying is also monitored by a specific monitoring activity. A phenological forecasting model for adult emergence, oviposition and larval emergence (overwintering, 1st and 2nd generation) is applied in IPM programs, and its predictions are spread by the bulletins. Mating disruption is applied in 10% of pomefruit surface, always combined with pesticides and codling moth granulovirus (CpGV). Granulovirus is applied in a third of the pomefruit surface. The use of IGR (IGR = insect growth regulator) is not the priority. When resistance to IGR is suspected (e.g. heavy damage at harvest is observed) or detected, they are not recommended. The IPM guidelines states the prohibitions on the total number of applications of each chemical or group of chemicals, taking into account all the pests, not only codling moth. The alternated use of products with different mode of action on each codling moth generation is recommended as a general antiresistance rule, but resistance to IGR and OP (OP = organo phospate insecticides) is already present even if not widespread. A limited number of populations are tested every year for resistance.

2.2.2 Trentino (Italy)

Almost only apples are grown in Trentino (12.500 ha). Codling moth has two generations per year. Population monitoring is carried out mainly with pheromone traps and fruit damage estimation during season. Catches in pheromone traps are not used as economic thresholds. Fruit damage is used to decide on pesticide applications. Forecasting models, based on phenology models for first adult emergence in spring, beginning of the oviposition, 1st damages and damages by 2nd generation are applied. Mating disruption combined with pesticides, when needed, is used by 30% of the growers. Granulovirus is rarely used, only in some specific situations. The most common situation includes an application of an IGR at the first oviposition period, and 2 more treatments using insecticides with a different mode of action. Only low level of resistance against IGR has been detected. The strategy is considered to be durable, as no important resistance problems have arise, although the population density has increased in the last years. The strategy is recommended to the single growers and as part of an Area wide Program when mating disruption is applied.

2.2.3 South Tyrol (Italy)

Only apples are grown is South Tyrol (18.000 ha). Integrated Pest Management is carried out in 90% of the surface, and there are 1.000 ha of organic apple orchards. The growers are well organised in the institution called Beratungsring, that includes about 4.000 growers (12.000 ha). About 90% of the growers receive the information produced by Beratungsring. Codling moth has two generations per year, and it is not a very important pest. Even without any control measure, 40% of the growers still would not have any damage.

Population monitoring is carried out mainly with pheromone traps, used by all of the extension officers and by some of the growers, and fruit damage estimation during season. Fruit damage is used as economic threshold. Forecasting models, based on phenology models are used by the extension officers by calculating the sum of temperature. No computer based model is used. Removing of fallen fruit at harvest and of damaged fruits at thinning are very common practices. Mating disruption (MD) is used by 75% of the growers, as the basic control strategy for more than ten years now. Only 20% of the growers combine MD with additional treatments, depending on the grower attitude against risk or damaged fruit samplings. The additional treatments are made with IGR or some other pesticides. The 25% of orchards without MD are in sites not suitable for it, and one insecticide application is usually enough. Granulovirus (CpGV) is used very rarely, because it never has been really effective in this area. Resistance management is carried out by all of the growers according to the guidelines of integrated pest control, e.g. alternation of products with different modes of action. In the nineties, some of the IGR showed a loss of effectiveness. This loss was analysed in the laboratory but it was only partly due to resistant populations. After the implementation of MD, the effectiveness of the IGR increased. The strategy is considered to be durable, being the increasing temperatures due to climatic change seen as a threaten.

2.2.4 Lake Constance (Germany)

Mostly apples are grown in the German part of the Lake Constance area (7.500 ha of apple orchards *vs.* 500 ha of pear orchards) around Ravensburg and Friedrichshafen). Consulting is carried out by official extension officers of the state and private consultants working for farmer associations, thus, the individual growers get information about various control strategies, which in some cases may result in some confusion. The reports edited by the official extension officers are communicated to the growers by fax or by phone, the private consultants use e-mail or fax.

Population monitoring is carried out mainly with pheromone traps run by the extension officers and by some of the growers. Only few growers carry out a precise monitoring of fruit damage during season. Fruit damage estimation at harvest is carried out by most of the growers and the results influence next year strategy. Forecasting models, based on the Swiss decision support system SOPRA are used to predict adult emergence of the 1st generation, oviposition, larval emergence and the development of subsequent populations. Sanitation practices are applied only if the damage is high. Mating disruption is applied by 15% of the growers, alone when included in a subsidized program, or combined with granulosis viruses, IGRs or other pesticides, depending on the severity of the pest. The priority use of IGRs is followed by most of the growers (80%). There is no resistance to conventional insecticides, but there is to some strains of granulovirus. So far, no resistance monitoring is made. Because of a more and more specific control against codling moth, secondary pests are increasing, e.g. other tortricids like Rose Leafroller and Smaller Fruit Tortrix. The increasing temperatures due to expected climatic change are thought to be a threaten.

2.2.5 Lake Constance (Switzerland)

Almost only apples are grown in the Swiss part of the Lake Constance area (1.400 ha in the Thurgau canton, and 205 ha plus 140.000 meadow apple trees in the St. Gallen canton). Integrated Pest Management is carried out in about 93 % of them, the residual 7% being organic. Consulting is carried out mainly by extension officers of the cantons. Additionally, the growers of the Thurgau area meet three to four times during the season.

Population monitoring is carried out with pheromone traps used by the extension officers and by about 20% of the growers, mainly the ones with big orchards. Precise damage monitoring, i.e. counting of percentages of damaged fruits, is rare. Forecasting models, based on the

Swiss decision support system SOPRA available in internet, are used to predict adult emergence of the 1st generation, oviposition, larval emergence and the development of subsequent populations. To determine the start of the flight, the pheromone traps are considered more important than SOPRA, afterwards decision making based on SOPRA becomes more important. No tolerance thresholds are used because of the high quality demands of the Swiss market. Sanitation measures, such as removal of damaged fruits and apples left behind after harvest, are carried out by most of the growers (90 %). Due to the presence of commercial meadow apple trees, were mating disruption can not be applied, the use of different types of IGR is the commonest method used in the St. Gallen area. Mating disruption is used by approx. 50% of the growers in the Thurgau canton, either alone (30 %) or combined with granulovirus or conventional insecticides. The installation of hail nets improves the effectiveness of mating disruption. The rest of the growers use IGRs as the first choice. No resistant populations have been detected in St. Gallen, but resistant populations against IGRs and against some strains of granulosis viruses, in organic orchards, occur in the Thurgau area. Monitoring of pesticide resistance is recommended by the extension officer but so far, not many growers follow the instructions. In mating disruption, some secondary pests like the Smaller fruit tortrix occur. The strategy is thought to be durable.

2.2.6 Netherlands

Apples and pears are grown in the Netherlands in similar surfaces (9.500 ha of apple orchards *vs.* 7.000 ha of pears).

Population monitoring is not carried out in a systematic basis. Pheromone traps are used by less than 25 % of the growers, due to the bad correlation between catches and damage. Fruit damage during season is not useful, as codling moth has only one generation. Fruit damage estimation at harvest is carried out by the majority of the growers, and the results influence next year strategy. Forecasting models, based on the phenology model RIMpro-cydia are used to predict adult emergence of the overwintering population, oviposition, and larval emergence. Many advisers use the model, so most of the growers benefit from the information. Several sprayings of granulovirus are applied by more than 50 % of the growers. Mating disruption is applied by less than 5% of the growers, alone or combined with granulovirus or IGRs. Up to 5 sprayings of pesticides other than IGRs are use by more than 90 % of the growers. The resistant measures recommended are the intensive spraying during important periods and the use of at least two different techniques or pesticides. There are no records of resistance, but the efficacy of the registered compounds is limited. The durability of the strategy is challenged by the emergence of secondary pests and the low efficacy of the chemicals registered.

2.2.7 Sweden

More apples than pears are grown in the Sweden (1.700 ha of apple orchards *vs.* 700 ha of pears).

Population monitoring is not carried out in a systematic basis. Pheromone traps are used by 5 % of the growers. Fruit damage during season is not useful, as codling moth has only one generation, and it not carried out. Forecasting models, based on the phenology model RIMpro-cydia are used to predict adult emergence of the overwintering population, oviposition, and larval emergence. The information is provided in an internet based warning system and it is used by the majority of the growers (70 %). Mating disruption is only used in organic orchards, as another pest, *Argysthia conjugella*, would need chemical sprayings anyhow. Granulovirus is not registered and, among the IGRs, only diflubenzuron is. Two applications of diflubenzuron and / or OPs are carried out by most of the growers. There are no records of resistant populations.

2.2.8 Rhône Valley (France)

Apples and pears are grown in the Rhône Valley in 8.000 and 3.500 ha, respectively. The information compiled through this questionnaire covers a sample of 4,100 ha of apple orchards and 1.350 ha of pear ones. In the Rhône Valley there is a North-South gradient on the number of codling moth generations. In the North, the first generation is complete and there is a second one partial, which can be important some years. On the other hand, in the South there are two complete generations, and a third partial, which very often is important.

Pheromone traps are set by less than 25 % of the growers, due to low reliability. Their results are mostly considered to initiate the phenological forecasting models, providing the kinetics of adult emergences, oviposition, and egg eclosion of the successive generations. Mating disruption is applied on close to 40% of apple and pear area, almost always combined with chemical pesticides in conventional orchards or with granulovirus (CpGV) in the organic ones. Mating disruption is often associated with a population survey through the assessment of fruit infestation at the end of the first generation and at harvest. The accuracy of this assessment allows to reduce the number of complementary insecticide against codling moth from 6-7 to 3 per year. The systematic use of CpGV is restricted to organic orchards, as organic growers have no alternative insecticides. Other growers apply a few CpGV at the beginning of the generations or before harvest. Insecticide resistance is a big problem in part of the area, addressing both chemical and microbiological insecticides. Precise instructions to prevent and manage resistance are given, but only followed by a few growers. The recent registration of new insecticides proved to be efficient against resistant populations and the restricted number of applications authorized for these new insecticides will lead to a better convergence between the practices and the recommendations, and in consequence improve strategy durability. The use of modified single row hail-nets to prevent codling moth injury is under experiment.

2.2.9 Lleida (Spain)

More pears than apples are grown in the Lleida area (9.300 ha of apple orchards *vs.* 14.000 ha of pear orchards). Integrated Pest Management is carried out in about 2.500 ha, and IPM guidelines for apples and pears are available for the growers. The pest control advisors meet every week and spread the information to the growers by means of bulletins. The information from the Plant Protection Service is available in internet.

Codling moth has three generations per year, but the third is partial, as a variable percentage of the larvae of the 2nd generation can diapause. Population monitoring is carried out mainly with pheromone traps and fruit damage estimation during season, both used in 100 % of the IPM area, sometimes by growers and sometimes by pest control advisors. Pheromone + pear ester traps is used by 50 % of the IPM growers, mainly in the mating disruption orchards. Fruit damage at harvest results are taken into account for the following year. Mainly fruit damage is used as economic thresholds, as catches are almost always above the tolerance level in non mating disruption orchards. Forecasting models, based on phenology models are used by the extension officers for 1st adult emergence, 1st oviposition and 1st larval emergence. An area wide spatial distribution program is carried out in part of the area. Mating disruption, always combined with IGRs and other pesticides, is compulsory for IPM growers, except when the conditions of the plots are not adequate. The use of granulovirus is small. Resistant populations have been detected, but the problem is not widespread. General rules to prevent resistance are given to the growers. The importance of secondary pests has not increased, due to the still widespread use of pesticides. The durability of the strategy is considered to be high.

2.3 *Elements of the strategy*

The information on the different elements of the strategy is shown in tables in the next sections. Each table includes the summary of the information of each element for all the regions. Note that in some cases the sum of regions is more the the number of regions as for example in Table 2.3.1.B and E. This means that there are differences within regions.

2.3.1. Population and Damage Monitoring

Monitoring of codling moth populations is carried out mainly with pheromone traps and by fruit damage estimation. The uses of pheromone traps (Table 2.3.1.A) is well established throughout the different regions, but complains on the reliability of this tool are frequent. Sometimes there is not a concordance between the captures and the actual fruit damage, and this leads to a lack of recommendation of this element in several areas. Consequently, the perception of the person interviewed in relation to the perspectives of use of the pheromone traps is some times negative or neutral (Netherlands, Rhône Valley and Trentino). The estimation of fruit damage during the season is widely recommended in most of the regions (Table 2.3.1.B), and it is considered a very important tool for decision making. This element is especially interesting in mating disrupted orchards where the pheromone traps become useless. However, fruit damage estimation is of little use in the regions where only one generation of codling moth occur (Netherlands and Sweden), as once damage is observed it is too late to react.

Corrugated cardboards are sometimes used (Table 2.3.1.C). However their use is usually not aimed to population monitoring, but to reduce infestation levels, especially in organic farming. On the other hand, the corrugated cardboards are also used for research purposes, such as establishment of correlations between pest density and monitoring systems or population collection for laboratory bioassays. The perspectives of use of this element in the future are negative, mainly because of the high labour cost that it implies. Nevertheless, it will be still used in organic farms.

The importance of pear ester combined with pheromone in delta traps is increasing. The use of these lures is not widespread through the different regions, but it is under development in many of them (Table 2.3.1.D). The use of pear ester plus pheromone is expected to be important in mating disrupted orchards, as they can catch individuals of both sexes. However, the relationship between the number of captures and the population density is still unknown, and tolerance thresholds are lacking. Once developed, this element will probably be long lasting in the strategy, especially regarding the growing importance of mating disruption.

The estimation of fruit damage at harvest is widely used and recommended through the studied regions (Table 2.3.1.E). This element gives valuable information for decision making in the next season, as it is a good indicator of population pressure for the next year. However, these estimations are not always made in the right way, and damage can be overestimated, what should be taken into account and corrected as much as possible. Most of the interviewed expect this element to stay in the strategy for long time.

Other monitoring tools occur, but they do in a minority way. This is the case of egg monitoring (Table 2.3.1.F), which is used in Emilia Romagna, where it is done at the province level.

Table 2.3.1.A. State of the art of pheromone traps use for codling moth population monitoring in 9 European apple and pear production regions. Figures show the number of regions.

Element of the strategy: Population Monitoring: Pheromone traps				
State of the art		**Ready**	**Under development**	
		9	0	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
		2	2	3
Obstacles	**None**	**Labour**	**Economic**	**Practical**
	X			
Use in practice (% of growers)		From 5% to 100% in IPM strategies.		

Table 2.3.1.B. State of the art of fruit damage estimation during season for codling moth population and damage monitoring in 9 European apple and pear production regions. Figures show the number of regions.

Element of the strategy: Population Monitoring: Fruit damage during season				
State of the art		**Ready**	**Under development**	
		9	1	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
		1	2	5
Obstacles	**None**	**Labour**	**Economic**	**Practical**
	X			
Use in practice (% of growers)		Ranging from few growers to almost all of them.		

Table 2.3.1.C. State of the art of the use of corrugated cardboards for codling moth population monitoring in 9 European apple and pear production regions. Figures show the number of regions.

Element of the strategy: Population Monitoring: Corrugated cardboards				
State of the art		**Ready**	**Under development**	
		9	0	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
		4	1	0
Obstacles	**None**	**Labour**	**Economic**	**Practical**
		X		
Use in practice (% of growers)		Very low, not even 5%. Only organic farms.		

Table 2.3.1.D. State of the art of pheromone + pear ester traps use for codling moth population monitoring in 9 European apple and pear production regions. Figures show the number of regions.

Element of the strategy: Population Monitoring: Pheromone + pear ester traps				
State of the art		**Ready**	**Under development**	
		0	4	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
		1	2	2
Obstacles	**None**	**Labour**	**Economic**	**Practical**
				X
Use in practice (% of growers)		Regionally used in Lleida and Rhone Valley (5%). In the remaining, the use is inexistent.		

Table 2.3.1.E. State of the art of fruit damage estimation at harvest for codling moth population and damage monitoring in 9 European apple and pear production regions. Figures show the number of regions.

Element of the strategy: Population Monitoring: Fruit damage at harvest				
State of the art		**Ready**	**Under development**	
		9	2	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
			3	5
Obstacles	**None**	**Labour**	**Economic**	**Practical**
	X			
Use in practice (% of growers)		From a few growers to almost all of them.		

Table 2.3.1.F. State of the art of egg monitoring for codling moth population monitoring in 9 European apple and pear production regions. Figures show the number of regions.

Element of the strategy: Population Monitoring: Egg Monitoring				
State of the art		**Ready**	**Under development**	
		0	1	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
Obstacles	**none**	**Labour**	**Economic**	**Practical**
				X
Use in practice (% of growers)		Experimental development in Emilia-Romagna.		

2.3.2. Use of Decision Support Systems

The use of DSS is widespread all over the regions of study. Phenology models for adult emergence, oviposition, larval emergence, and subsequent generations are used in most of the regions (Tables 2.3.2.A to D). Many of the phenology models predict all these phenological events. Concretely RIMpro-cydia and SOPRA are very used, but other models also exist. The consideration of subsequent generations is meaningless in the regions were only one generation occurs (i.e. Sweden, Netherlands). The use of these models is usually linked to IPM programs, whereas conventional growers do not use them that much. Interestingly, all the interviewed persons agree that the perspectives for further implementation of the use of the models are positive.

There are also tolerance thresholds established in several regions (Table 3.2.3.E), but their use is not as common as that of phenology models.

Finally, orchard history is also used as a making-decision tool, as information about pest incidence in the precedent year can give good information about initial pest pressure for the year after.

Table 2.3.2.A. State of the art of the use of phenology models for codling moth adult emergence within Decision Support Systems in 9 European apple and pear production regions. Figures show the number of regions.

<table>
<tr><td colspan="5">Element of the strategy: Decision Support Systems: Phenology models for adult emergence</td></tr>
<tr><td colspan="2" rowspan="2">State of the art</td><td>Ready</td><td colspan="2">Under development</td></tr>
<tr><td>8</td><td colspan="2">3</td></tr>
<tr><td colspan="2" rowspan="2">Perspectives for (further) implementation</td><td>Negative</td><td>Neutral</td><td>Positive</td></tr>
<tr><td>0</td><td>0</td><td>6</td></tr>
<tr><td rowspan="2">Obstacles</td><td>None</td><td>Labour</td><td>Economic</td><td>Practical</td></tr>
<tr><td>X</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Use in practice (% of growers)</td><td colspan="3">Very variable. Almost 100% among IPM growers, but few amongst the non-IPM growers.</td></tr>
</table>

Table 2.3.2.B. State of the art of the use of phenology models for codling moth oviposition within Decision Support Systems in 9 European apple and pear production regions. Figures show the number of regions.

<table>
<tr><td colspan="5">Element of the strategy: Decision Support Systems: Phenology models for oviposition</td></tr>
<tr><td colspan="2" rowspan="2">State of the art</td><td>Ready</td><td colspan="2">Under development</td></tr>
<tr><td>8</td><td colspan="2">3</td></tr>
<tr><td colspan="2" rowspan="2">Perspectives for (further) implementation</td><td>Negative</td><td>Neutral</td><td>Positive</td></tr>
<tr><td>0</td><td>0</td><td>7</td></tr>
<tr><td rowspan="2">Obstacles</td><td>None</td><td>Labour</td><td>Economic</td><td>Practical</td></tr>
<tr><td>X</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Use in practice (% of growers)</td><td colspan="3">Very variable, but lower than for the adult emergence models.</td></tr>
</table>

Table 2.3.2.C. State of the art of the use of phenology models for codling moth larval emergence within Decision Support Systems in 9 European apple and pear production regions. Figures show the number of regions.

<table>
<tr><td colspan="5">Element of the strategy: Decision Support Systems: Phenology models for larval emergence</td></tr>
<tr><td colspan="2" rowspan="2">State of the art</td><td>Ready</td><td colspan="2">Under development</td></tr>
<tr><td>9</td><td colspan="2">2</td></tr>
<tr><td colspan="2" rowspan="2">Perspectives for (further) implementation</td><td>Negative</td><td>Neutral</td><td>Positive</td></tr>
<tr><td>0</td><td>0</td><td>6</td></tr>
<tr><td rowspan="2">Obstacles</td><td>None</td><td>Labour</td><td>Economic</td><td>Practical</td></tr>
<tr><td>X</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Use in practice (% of growers)</td><td colspan="3">Very variable. Almost 100% among IPM growers, but few amongst the non-IPM growers.</td></tr>
</table>

Table 2.3.2.D. State of the art of the use of phenology models for subsequent generations of codling moth within Decision Support Systems in 9 European apple and pear production regions. Figures show the number of regions.

Element of the strategy: Decision Support Systems: Phenology models for subsequent generations				
State of the art		**Ready**	**Under development**	
		8	3	
Perspectives for (further) implementation		**Negative**	**Neutral**	**positive**
		0	1	6
Obstacles	**None**	**Labour**	**Economic**	**Practical**
	X			
Use in practice (% of growers)		Variable. 90% Rhone Valley.		

Table 2.3.2.E. State of the art of the use of tolerance thresholds for codling moth within Decision Support Systems in 9 European apple and pear production regions

Element of the strategy: Decision Support Systems: Tolerance Thresholds				
State of the art		**Ready**	**Under development**	
		5	2	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
		0	1	3
Obstacles	**None**	**Labour**	**Economic**	**Practical**
	X			
Use in practice (% of growers)		Lower than for phenology models.		

2.3.3. Orchard Management Practices and Use of Sanitation Practices

Orchard management practices and sanitation practices are, in general, of little important in the control strategies of codling moth. However, there are a few of them that sometimes are used to complement the main control tools. Removal of damaged fruits (Table 2.3.3.) is the most important among them. This sanitation practice is hardly ever done with the only objective of eliminate codling moth from the orchard, but it is usually done at thinning time. In organic farming it is used more often than under conventional production.

Other practices are avoidance of wood stacks near to the orchards, treatment of meadow host-trees with insect ides, destruction of fallen fruits, and removal or destruction of unharvested fruits, which otherwise can allow larvae to complete their development. The incidence of these practices on codling moth control is difficult to estimate, but their impact is usually low. The application of these practices is not homogeneous throughout the studied regions, and often a practice is widely used in a region, but it is not used at all in others.

Table 2.3.3. State of the art of the use of removal of damaged fruit for codling moth control in 9 European apple and pear production regions. Figures show the number of regions.

Element of the strategy: Management and Sanitation Practices: Removal of damaged fruits				
State of the art		**Ready**	**Under development**	
		8	0	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
		0	2	3
Obstacles	**None**	**Labour**	**Economic**	**Practical**
		X		
Use in practice (% of growers)		Variable. Among 0% and 50% of farmers.		

2.3.4. Non-Chemical Control Methods

Among the non-chemical control methods against codling moth, mating disruption is doubtless the most important and widely spread one (Table 2.3.4.A). In fact, codling moth control strategies can be divided into two groups, depending on whether mating disruption is used or not. The use of mating disruption alone is scarce, usually not recommended, and it is often restricted to plots with low codling moth population density, especially of early pears (Table 2.3.4.B). In most cases, mating disruption is combined with insecticides, both chemical and microbial ones. In some regions, it is common to combine mating disruption with granulovirus (CpGV) (Table 2.3.4.C), and in other regions it is more common to combine it with IGRs (Table 2.3.4.D) or other chemical pesticides (Table 2.3.4.E). The perspectives of the use of mating disruption for codling moth control are positives, but it is not so clear in the case of mating disruption alone. The general agreement is that mating disruption is an environmentally-safe technique, that matches IPM and organic production restrictions, and which is compatible with almost the totality of the other control techniques, giving a satisfactory control success. The main drawbacks of mating disruption are the price of the pheromone dispensers and the labour cost associated to their placement in the orchard. These drawbacks are expected to lose importance in the future with the development of sprayable formulations and the puffers (punctual area-wide dispensers), which at present are under development. The risk of development of resistance to mating disruption has not been mentioned, but can not be forgotten.

Granulovirus (CpGV) is used in some regions (Table 2.3.4.F). It usually applied in combination with the other control methods, as its action is at the long-term. The treatments are usually concentrated in the peak flights, and they are made every 7-10 days. It is sometimes also applied close to harvest to avoid the problems of safe-to harvest intervals. The perspectives of use of CpGV are globally positive, especially combined with mating disruption. The use of CpGV is limited by the environmental conditions of regions where summer is too hot and dry (Lleida), and by the absence of registration (Sweden).

Biological control of codling moth is not important from an agricultural point of view, except the use of gronulovirus. The low tolerance thresholds of the pest together with the endophytic behaviour of the larvae makes biological control of little importance, and it is in consequence neglected in the codling moth control strategies (Table 2.3.6.G).

There are other non-chemical methods which are under development. This is the case of the entomopathogenic nematodes (Table 2.3.4.H) and hail nets (Table 2.3.4.I). The incorporation of the entomopathogenic nematodes to the control strategy of codling moth is expected to be positive in general, but as for CpGV, their use will be conditioned by the regional weather conditions (rain, in this case). The use of hail nets is at the very beginning of development, and it will be important to know how these will affect to some quality aspects of the fruits.

Table 2.3.4.A. State of the art of the use of mating disruption for codling moth control in 9 European apple and pear production regions. Figures show the number of regions.

Element of the strategy: Non-Chemical Control Methods: Mating disruption (global)				
State of the art		**Ready**	**Under development**	
		8 (9)	2	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
		0	3	5
Obstacles	**None**	**Labour**	**Economic**	**Practical**
		X	X	
Use in practice (% of growers)		25% may be a realistic average, but it is very variable among regions and growers. More used by organic and IPM-growers.		

Table 2.3.4.B. State of the art of the use of mating disruption alone for codling moth control in 9 European apple and pear production regions. Figures show the number of regions.

Element of the strategy: Non-Chemical Control Methods: Mating disruption alone				
State of the art		**Ready**	**Under development**	
		8	1	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
		1	1	2
Obstacles	**none**	**Labour**	**Economic**	**Practical**
		X	X	X
Use in practice (% of growers)		Very low.		

Table 2.3.4.C. State of the art of the use of mating disruption + granulovirus (CpGV) for codling moth control in 9 European apple and pear production regions. Figures show the number of regions.

Element of the strategy: Non-Chemical Control Methods: Mating disruption plus CpGV				
State of the art		**Ready**	**Under development**	
		8	1	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
		0	1	4
Obstacles	**none**	**Labour**	**Economic**	**Practical**
		X	X	
Use in practice (% of growers)		Low. Usually combined with IGRs and other insecticides.		

Table 2.3.4.D. State of the art of the use of mating disruption + IGRs for codling moth control in 9 European apple and pear production regions. Figures show the number of regions.

Element of the strategy: Non-Chemical Control Methods: Mating disruption plus IGRs				
State of the art		**Ready**	**Under development**	
		8	0	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
		0	1	4
Obstacles	**None**	**Labour**	**Economic**	**Practical**
		X	X	
Use in practice (% of growers)		Low. Usually also with other insecticides		

Table 2.3.4.E. State of the art of the use of mating disruption + other insecticides for codling moth control in 9 European apple and pear production regions. Figures show the number of regions.

Element of the strategy: Non-Chemical Control Methods: Mating disruption plus other insecticides				
State of the art		**Ready**	**Under development**	
		8	0	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
		0	1	4
Obstacles	**None**	**Labour**	**Economic**	**Practical**
		X	X	
Use in practice (% of growers)		Low. Often combined with IGRs.		

Table 2.3.4.F. State of the art of the use of granulovirus for codling moth control in 9 European apple and pear production regions. Figures show the number of regions.

Element of the strategy: Non-Chemical Control Methods: Granulovirus (CpGV)				
State of the art		**Ready**	**Under development**	
		8	1	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
		0	1	2
Obstacles	**None**	**Labour**	**Economic**	**Practical**
				X
Use in practice (% of growers)		High variability among regions, although it is not used alone.		

Table 2.3.4.G. State of the art of codling moth biological control in 9 European apple and pear production regions. Figures show the number of regions.

Element of the strategy: Non-Chemical Control Methods: Biological Control				
State of the art		**Ready**	**Under development**	
		0	2	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
		1	2	0
Obstacles	**None**	**Labour**	**Economic**	**Practical**
				X
Use in practice (% of growers)		0%		

Table 2.3.4.H. State of the art of the use of entomopathogenic nematodes for codling moth control in 9 European apple and pear production regions. Figures show the number of regions.

Element of the strategy: Non-Chemical Control Methods: Entomopathogenic Nematodes				
State of the art		**Ready**	**Under development**	
		0	4	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
		0	3	2
Obstacles	**None**	**Labour**	**Economic**	**Practical**
				X
Use in practice (% of growers)		Only experimental.		

Table 2.3.4.I. State of the art of the use of hail nets for codling moth control in 9 European apple and pear production regions. Figures show the number of regions.

Element of the strategy: Non-Chemical Control Methods: Hail Nets				
State of the art		**Ready**	**Under development**	
		0	1	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
		0	0	1
Obstacles	**None**	**Labour**	**Economic**	**Practical**
				X
Use in practice (% of growers)		Basically experimental.		

2.3.5. Chemical Control Methods

Chemical control methods are the most widespread methods in codling moth control strategies all over Europe. In some cases, IGRs are given priority over other chemical insecticides, but wide spectrum insecticides are by far the most used ones, especially in the warm areas. In fact the restrictions on the availability of active matters are a major concern in the control of codling moth in Europe.

Table 2.3.5.A shows the collected information on the priority use of IGRs. The use of IGRs is sometimes not recommended if heavy attacks have taken place in the previous year. The number and interval of treatments depend on the severity of the pest, and there are also different considerations in their use depending on the region. However, the use of IGRs is usually recommended for the first generation. Alternation in the use of IGRs occurs in all regions where they are used (Table 2.3.5.B), and it is linked to the management of insecticide resistance. Different approaches are used for the management of IGR alternation in the different regions.

The use of other insecticides is very common (Table 2.3.5.C), especially in the warmest regions, where codling moth is multivoltine and pest pressure is higher. In general, all the registered active matters are used, but some of them are more commonly used: ethyl-chlorpyrifos, thiachloprid, methyl-azinphos and phosmet. Some insecticides with short safe-to-harvest intervals are used close to harvest (malathion). Some of the mentioned ones are already or are about to be forbidden in the EU.

Table 2.3.5.A. State of the art of the use of IGRs for codling moth control methods in 9 European apple and pear production regions. Figures show the number of regions.

Element of the strategy: Chemical Control Methods: Priority use of IGRs				
State of the art		**Ready**	**Under development**	
		5	0	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
		1	1	2
Obstacles	**None**	**Labour**	**Economic**	**Practical**
	X			
Use in practice (% of growers)		20%		

Table 2.3.5.B. State of the art of the use of alternation of IGRs for codling moth control methods in 9 European apple and pear production regions. Figures show the number of regions.

Element of the strategy: Chemical Control Methods: Alternation in the use of IGRs				
State of the art		**Ready**	**Under development**	
		7	0	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
		0	0	2
Obstacles	**None**	**Labour**	**Economic**	**Practical**
	X			
Use in practice (% of growers)		80%		

Table 2.3.5.C. State of the art of the use of other pesticide for codling moth control methods in 9 European apple and pear production regions. Figures show the number of regions.

Element of the strategy: Chemical Control Methods: Other pesticides				
State of the art		**Ready**	**Under development**	
		9	0	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
		0	0	3
Obstacles	**None**	**Labour**	**Economic**	**Practical**
	X			
Use in practice (% of growers)		75%		

2.3.6. Pesticide Resistance Management and Resistant Populations

Pesticide resistance management is a very important element in the control strategy. Especially nowadays, because many cases of resistant have been found and the number of permitted active matters has being reduced. In some areas, resistance monitoring is used, and in others it is under development (Table 2.3.6.A). Resistance monitoring is expected to have a positive impact on the control strategies of codling moth.

For the management of the resistance, there are both precise instructions and general rules in several regions (Tables 2.3.6.B and C). These precise instructions and general rules are usually found together in the same regions, and sometimes they are under development. In both cases the perspectives of use are considered positives.

Resistant populations occur in all studied regions, but Sweden, where only one spray per year is carried out. Resistant populations to several chemical insecticides (OPs, IGRs, pyrethroids and benzoyl ureas) are known, but also to CpGV (Rhône Valley, Lake Constance and The Netherlands). The evidences of occurrence of resistance vary among regions from just empirical observations (increasing number of necessary sprays, or low efficacy of insecticide sprays) to laboratory bioassays (Trentino, South Tyrol, The Netherlands, Rhone Valley, and Lleida).

Table 2.3.6.A. State of the art of codling moth pesticide resistance monitoring in 9 European apple and pear production regions. Figures show the number of regions.

Element of the strategy: Pesticide Resistance Management: Resistance monitoring				
State of the art		**Ready**	**Under development**	
		4	3	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
			1	2
Obstacles	**None**	**Labour**	**Economic**	**Practical**
	X			
Use in practice (% of growers)				

Table 2.3.6.B. State of the art of codling moth pesticide management resistance in 9 European apple and pear production regions

Element of the strategy: Pesticide Resistance Management: Precise Instructions				
State of the art		**Ready**	**Under development**	
		3	3	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
		0	0	2
Obstacles	**none**	**Labour**	**Economic**	**Practical**
	X			
Use in practice (% of growers)				

Table 2.3.6.C. State of the art of codling moth pesticide resistance management in 9 European apple and pear production regions

Element of the strategy: Pesticide Resistance Management: General Rules				
State of the art		**Ready**	**Under development**	
		4	3	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
		0	0	2
Obstacles	**None**	**Labour**	**Economic**	**Practical**
	X			
Use in practice (% of growers)				

2.3.7. Emergence of Secondary Pests

The importance of emerging secondary pests is variable among regions. In some regions this aspect is completely absent (Lleida and Emilia Romagna) or marginal (Lake Constance) whereas in other is a major concern (The Netherlands).

Among the emerging secondary pests are several tortricids (i.e. summer fruit tortrix and oriental fruit moth), aphids (woolly apple aphid and rosy apple aphid), apple clearwig, tigger moth, apple sawfly, pear psylla and San Jose scale. The emergence of these secondary pests can be due to either a decrease in the number of chemical insecticides which previously controlled the pests, or to the side effects of the insecticides used for codling moth control on the natural enemies of some of those pests.

2.4 *Durability of the strategy*

Most of the enquired people think that the current strategies are durable. Combination of mating disruption and insecticide methods has been used for many years in several regions and no problems of resistance to the mating disruption have appeared yet. For this reason it is thought that this kind of strategy can be long lasting. In many areas, the surface of mating disruption has increased lately and it still does. This increase has been often a consequence of the appearance of resistant populations either to chemical insecticides or to CpGV, what has led to a decrease of the insecticide treatment efficacy. Other major concerns regarding to the sustainability of the strategies are the emergence of secondary pests, the decrease in the number of active matters available and the lack of new ones, as well as climate change. The severity of the pest has been found to increase lately in several regions, and this increase can be someway link to the global warming, as suggested by the increase of the 3rd generation in those areas where the pest has classically had 2 complete generations and a partial third.
It seems that the different strategies of all the regions are, step by step, going to the global use of mating disruption combined with CpGV or natural enemy friendly chemical insecticides (especially in these areas where environmental factors make the use of CpGV risky or useless).

2.5 *Bottlenecks (social, economic, technical)*

Major bottlenecks are mainly linked to mating disruption spreading and insecticide availability. Bottlenecks for mating disruption spreading may be economical, practical or social. Mating disruption is a technique that implies high costs because of the labour costs and the price of the dispensers. Moreover, it requires medium to large surfaces because in small plots hardly ever performs adequately, this makes necessary that growers in a given area agree on using all of them this technique. There are also some other situations that difficult the use of mating disruption, such as hillsides, meadow trees or windy areas. On the other hand, the use of mating disruption and the subsequent decrease in insecticide sprays may favour the emergence of secondary pest. Finally, from a social point of view, growers are not always open minded, and some of them prefer to keep on conventional control just because of their habits. And in some regions advice is given by commercial technicians, who might be biased towards conventional chemical control.

Regarding to insecticides the bottlenecks that can be found are usually practical. They are related to the lack of efficacy of the treatments because of the appearance of resistant populations, and the absence of new active matters. This lack of efficacy on the insecticide sprays leads to an increase in their number and frequency, and to an increase of costs, in consequence.

Doubtless the major market concern is pesticide residues in fruits. This concern can be considered from two points of view. First, there is a clear problem related to the efficacy of insecticide treatments. These are less and less effective, which implies an increase in the number of treatments, and in consequence on the level of insecticide residues on fruits (or at least an increased risk of). From the other side, the tolerance level of residues on fruit is decreasing, and it makes more difficult pest control for the growers, if they do not want to increase the risk of overcoming the limits.

2.6 *Conclusions*

Although it is impossible to draw conclusions that apply to 100% of the area investigated, the general conclusions are:

- Codling moth population monitoring is carried out by pheromone traps and the estimation of fruit damage during the season and/or at harvest. The use of pheromone traps is limited by the lack of correlation between catches and damage sometimes observed.
- The use of pheromone plus pear ester traps is seen as a tool to be explored.
- Phenology models for adult emergence, oviposition, larval emergence, and subsequent generations are used in most of the regions. The perspectives for their further implementation are positive.
- Orchard management and sanitation practices are, in general, of little importance in the control strategies of codling moth.
- In the regions where codling moth is an important problem, due to the number of generations, the combined use of mating disruption and microbial and conventional insecticides is recommended and used in most of the areas under IPM strategies. The perspectives of the use of mating disruption for codling moth control are positives, although it is a technique that has agronomical and technical limitations. The existence of Area Wide Management Programs will help to overcome them. The main drawbacks of mating disruption are the price of the pheromone dispensers and the labour cost associated to their placement in the orchard.
- The perspectives of use of CpGV are globally positive, especially combined with mating disruption
- Biological control of codling moth is not important in any region except the use of granulovirus.
- The use of insecticides is very common as it is the main control measure in the absence of mating disruption. Programs for insecticide resistance monitoring are well developed in some regions and are seen as a key aspect of the durability of the strategy. However, the general or precise rules for insecticide resistance management are not applied by the growers as precisely and frequently as desired.
- The importance of emerging secondary pests is variable among regions, being absent in some of them.
- Most of the enquired people think that the current strategies are durable. Major concerns are the emergence of secondary pests, the decrease in the number of active ingredients available and the lack of new ones, and the possible effects of climate change.
- Major bottlenecks are linked to mating disruption spreading and insecticide availability. Bottlenecks for mating disruption spreading may be economical, practical or social.
- Pesticide residues in fruits have been signalled almost unanimously as the major market concern.

It is noted that about IPM management of codling moth there are some major tools that must be always included in the protection strategy. These tools are Decision Support Systems, Damage Monitoring, Mating Disruption, and insecticides (including bio insecticides). On the other hand, sanitation practices can be skipped. Despite sanitation practices can have a good impact on the management of populations, they are to time costly, and in consequence economically too. Finally, there are some tools that are still under development and they could have a good acceptance in the management strategies in the future; such is the case of the use of the adapted hail nets.

There is a general weaknesses of IPM management through Europe. There is a need to uniform the registration of control tools through Europe. The current situation makes more difficult the standardization of IPM guidelines (or policy) in Europe, as some tools are registered only in some countries. On the other hand, we want to emphasize the importance of considering IPM control of codling moth with multi-annual and area-wide criteria. The application of IPM strategies for the control of this pest in a year after year and local way is drawback for the implementation of IPM itself. Incentives from public, governments or supermarket chains might stimulate further use of IPM. Especially, agreements with the retailers might be helpful to further implement IPM.

3 Survey of the state of the art of brown spot integrated control strategies

3.1 *Questionnaire and regions covered*

In the European Cost 684 project a network of researchers on crop protection in pome fruit was established. From this network and the results of Endure Deliverable DR1.7 it was found that problems with brown spot on pear are very serious in only a few European regions. These regions are Emilia Romanga (Italy), Catalonia (Spain), Belgium, The Netherlands and to a lesser extent Rhone Valley. Questionnaires were send to representatives in these regions (table 3.1.1).

Table 3.1.1. Information about the regions covered by the answers to the questionnaires related to brown spot of pear.

Region (Country)	**Contact person**	**Institution**	**Orchard Surface (ha)**
1. Emilia Romagna (Italy)	Riccardo Bugiani & Marina Collina	Plant Protection Service - Emilia Romagna; University of Bologna	Pear: 26.290
2. Catalonia (Spain)	Emilio Montesinos & Isidre Llorente	University of Girona	Pear: 14.000
3. Belgium	Piet Creemers & Stein van Laer	PCFruit Research Station of Gorsem	Pear: 8.000
4. The Netherlands	Peter Frans de Jong & Bart Heijne	Applied Plant Research, Randwijk	Pear: 7.000

3.2 *Description of the whole strategy per region*

3.2.1 Emilia Romagna (Italy)

Emilia Romagna is situated in the Po valley in the north of Italy and has a warm and relatively humid climate. Rain occurs mainly in two periods: first in spring (March to mid May) and then in autumn (from October-November). Usually in this periods heavy rains are possible. The climatically conditions in Emilia Romagna are considered favourable to the development of brown spot of pear. Pear is by far the main fruit crop grown in Emilia Romagna with nearly 26.300 ha. Roughly about one third of this pear area is produced under integrated control regulation. The Plant Protection Service provides weekly bulletins to growers with actual information in printed version and more and more often by sms on cellular phones.

The strategies against brown spot of pear consists of fungicide applications, sanitation practices and the use of resistant cultivars. Use of decision support systems is widely used in the region with more than 500 users. BSP-cast + SPOR is the system used in Emilia-Romagna. The models are run at provincial level and information is diffused through bulletin, email and sms to farmers and field technicians. Information is given about the airborne conidia and climatic driven infections. Feedbacks are provided by farmers to the extension persons and in the last 2-3 years an increasing numbers of growers join the provincial warning service in Ferrara. Only some farmers are able to do weather observations themselves. Monitoring is performed both in commercial orchards and ad-hoc unsprayed plots by field technicians about the occurrence of the disease during the growing season irrespective of primary and secondary infections. The decision support systems are used to start the sprays against brown spot and secondly to correctly time the sprays and/or widen

the interval between the sprays. The potential inoculum present in the orchards in the 2 previous years are used to differentiate orchards into “high risk” and “low risk” orchards. Such difference determine the control strategy in terms of product to be used. Sprays are carried out on 4 to 10 days interval bases depending of the active ingredient and risk of infection. Kresoxym-methyl, trifloxystrobin, iprodione, thiram, copper compounds, fludioxonil + ciprodinil, pyraclostrobin + boscalid, boscalid, tebuconazole and captan are the most important fungicides used. The choice which pesticide will be used is lead by activity, toxicity for humans and environment, prices and residues. Organic farmers, which represent 15 % of the pear growing area use copper compounds. The antagonist *Trichoderma* is being tested as sprays on orchard lawn, but this method is still at experimental level.
Resistance of *S. vesicarium* against fungicides is a problem in Emilia Romagna due to the high number of sprays performed each season. Problems are encountered particularly with dicarboximides (procimidone) and studies are currently being made on fludioxonil + cyprodinil and strobilurines. Resistance to procimidone and tryfloxystrobin have been proved in the laboratory. Strobilurine resistance is so far limited to very few orchards. Procimidone resistance is widely spread in the region but if it is not used for 4-5 years the fungal population usually turn susceptible to the fungicide again. And procimidone is no longer permitted at European level on pear. The mixture fludioxonil + cyprodinil and also thiram sometimes have an efficacy problem even though not yet related to resistance pathogen populations. FRAC recommendations for specific fungicides are used to avoid problems with resistance to fungicides.

Sanitation practices are used to a limited scale in Emilia Romagna. The control of the leaf litter is used rarely, at most by 5 % of the growers and only by those growers who have very serious problems with brown spot. The cultivar susceptibility does no influence the use of sanitation practices in Emilia Romagna.

There are differences in the susceptibility to brown spot of pear between cultivars grown in Emilia Romagna. Abbè Fetel, Gen. Leclerc and Conference are susceptible, Doyenne de Comice is fairly susceptible, and Kaiser William is resistant. Abbè Fetel is by far the most commonly grown cultivar, Conference is the second one and Kaiser William the third one.
All the others are less important. In making the choice which cultivar will be planted the susceptibility to brown spot is not taken into account. No strategy is used to profit from resistance of different cultivars, such as mixing cultivars in an orchard.
Resistant cultivars are treated with fungicides, but less often. This is depending on the risk for other diseases; for example pear scab is the most common disease on Kaiser William which in turn is resistant to brown spot. So far no resistance breakdown has been observed.
Recently the appearance of a new disease has been proven. It is Valsa canker or Cytospora canker which is caused by two species of fungi, *Leucocytospora cincta* and *Leucocytospora leucostoma*. However other source report V*alsa ceratosperma* (Tode ex Fr.) as the causal agent. It was observed in the area in 2001 but a recent monitoring proved that is widespread in the region.

In conclusion it can be said that the disease can be controlled in Emilia Romagna at the moment. The situation is stable. There are no problems with the emergence of secondary pests or beneficial insects. But problems will occur in future due to banning of products due to enforcing the EU 91/414 regulation. Till now the control of brown spot of pear in Emilia Romagna is much dependent on fungicide use. There are gaps in the knowledge! But so far we start to know more than in the past. New information was found on the relationship between physiology of the plant and the disease and on the influence of plant nutrition on the disease.

3.2.2 Catalonia (Spain)

The Provence of Catalonia is situated in the north east of Spain. It has warm and in some periods relatively humid climate. During all the year rainfall is possible but normally the higher quantity of rain occurs during spring (mainly from April to June) and autumn (from middle August to November), in total between 600 and 750 mm. Especially during spring, the weather conditions in Catalonia are considered favourable for the development of brown spot of pear. Pear is an important fruit crop in Catalonia, with in total 4000 ha of which 200 ha is situated in Girona and the remainder in Lleida and La Rioja. The average size of pear orchards is about 10 ha. The majority of pears are grafted on rootstocks, mainly quince: BA29, Sydo and Adams. The severity of brown spot on pear is regarded as high and is an serious problem of pear cultivation in the area.

In general, the strategies to control brown spot of pear is mainly focussed on intelligent use of fungicides either or not combined with sanitation practices. The latter mainly consist of the use of urea. Irrigation systems are widely used in the region, both drip irrigation and surface irrigation. This means that the foliage is not wetted. No specific cultural measures, such as conservative nitrogen nutrition or improvement of soil activity, are taken to support brown spot control.
Decision support systems are widely used. The BSPcast forecasting system, originally developed in the University of Girona, is used. The warning stations are installed and managed by the Department of Plant Health of the Government of Catalonia. The stations are well distributed in the region. The weather stations have sensors for rain, leaf wetness, temperature and other parameters. Together with the BSPcast system a risk of infection is predicted. Fruit growers have direct access to the data form the stations and to the forecasting models. Technical fruit consultants give feedback from growers on the results of the system.
Strategies are communicated by means of the web, SMS and e-mail. The most relevant websites to the farmers are:

- http://www.ruralcat.net/ruralcatApp/agrometeo/html/agrometeo.htm?gencat=2
- http://www.ruralcat.net/ruralcatApp/notiactualitat.ruralcat?sectorid=192&tipoIdName=INFOBASE&contentId=9860&content=/infobase/jsp/infobase.jsp
- http://www20.gencat.cat/portal/site/DAR

Monitoring of brown spot in the orchards is periodically done by the technicians to evaluate the evolution of lesions on leaves and fruits. There is a specific protocol for disease assessment. In spite of use the decision support system BSPcast, preventive treatments are performed because producers do not want to take the risk of losses due to the fact that disease forecasting is based on regional weather parameters and taken from the local orchards. Main fungicides used against brown spot of pear are thiram (TMTD) at a 7 days interval, strobilurines (kresoxym-methyl (Stroby)), trifloxystrobin (Flint) and procimidone (Folicur) at a 10 days interval and captan at a 7 days interval. Normally, the fungicide choice is primarily based on efficacy and then price of the products. The management to delay or prevent development of resistance to fungicides consists on the alternation of fungicides and the limitation of the number of sprays. Systemic fungicides such as strobilurines are applied at maximum of three times and the applications are alternated using other contact fungicides as thiram or captan. Till now No resistances have been described. However, probably kresoxim-methyl was more effective during first years. In the beginning, the applications were performed every 14 days and nowadays the interval is shortened and kresoxim-methyl is applied every 7 -10 days.

Sanitation practices are used to some extent in Catalonia. The control of the leaf litter is not used. But normally, affected orchards are sprayed with urea in autumn. This is done by 50 % of the fruit growers. The cultivar susceptibility does no influence the use of sanitation practices in Catalonia.

The main pear cultivars grown in Catalonia are Conference (75 % of the acreage), Abate Fetel (10 %), Doyenné de Comice (5 %) and Passe Crassane (5 %). They are all susceptible to brown spot of pear. From the remaining cultivars (5 % of the acreage) William's and Blanquilla have a high degree of resistance. Since all cultivars are susceptible to brown spot of pear there is no resistance management. The cultivars are mixed in order to pollinate the main cultivar. The brown spot resistant trees are still treated with fungicides, but about 50 % less than susceptible cultivars. However, if in the orchard non-susceptible cultivars are mixed with susceptible cultivars, then the sprays are the same in the entire orchard.
No new diseases are observed in pear in Catalonia.

It can be concluded that the current strategy is not durable. This is because the number of treatments is high and the level of residues and legal restrictions will limit the use of these fungicides. In fact, some fungicides like ziram, procimidone and tolylfluanide are not registered anymore today. At the moment the disease is stable in Girona, probably due to the high pressure of fungicide treatments. When in an orchard no fungicides are applied, the disease increases considerably. In the regions Lleida and La Rioja and some other regions, the disease is increasing. For the moment, the most important approach are the use of fungicide sprays and sanitation methods. In the future, an important goal will be to obtain resistant cultivars, but in breeding programs is not easy to obtain new cultivars based upon resistance to brown spot.
The gaps in the knowledge are related to biology and the life cycle of *Stemphylium vesicarium* / *Pleospora allii*. It is important to complete the knowledge on the biology and the life cycle to attend the origin of inoculum during the vegetative period. There is an urgent necessity for new fungicides and biocontrol agents.

3.2.3 The Netherlands

The Netherlands has a typical temperate climate. This means relatively cool summers with an average temperature of 17 º C and moderately cold winters with average temperature of 3 º C. Rainfall is quite regularly spread over the months with an average of 50 to 70 mm each month and in total 775 to 825 mm each year. This results in a rainfall surplus of 200 to 240 mm per year. Typically, the weather is very variable. This means that rainfall occurs quite regularly, but also dry spells of 2 to 3 weeks can occur. This weather is conducible for development of brown spot in pear. However, non-proven ideas state that warmer and wetter conditions than average in the months May to August aggravate of the disease. Severity of the disease is low on average. But very severe outbreaks of the disease occur incidentally every year, with dramatic losses. This has resulted in a great fear for the disease. No cultural methods are taken specifically for brown spot of pear. The majority of pear orchards have drip fertigation in spite of the rain surplus. Incidentally, overhead sprinklers are used to cool the crop during extreme warm days in summer. The importance and acreage of pear is gradually growing in the Netherlands. Now the acreage is about 7000 ha, spread over different regions of the country. Nearly all pears are grown according to integrated control strategies in which the natural control of spider mites, rust mites and pear psylla are the cornerstones of the system. No governmental system of advice or actual information exists. The majority of the growers have contracts with private advisor organisations. Communication is through internet, e-mail and fax, combined with farm visits.

The control of brown spot of pear nearly completely depends on the use of fungicide applications. A decision support system is under development in the Netherlands. It is based on the BSPcast model from University of Girona, but adapted with adding the prediction for spore presence. A draft version, called Stemphy (company Bodata), is commercially available for all growers in combination with advisor support. A network of weather stations exists in the Netherlands. The availability of the weather data is diverse. Some growers have their own weather station, others are owned by advisory organisations. Most information on weather conditions and advices from warning systems is distributed through private advisory organisations. There is no system of monitoring the disease in the Netherlands. Till now only a limited number of fruit growers use the information from the Stemphy warning system. But the ones who use the system, apply fewer sprays specifically against brown spot in pear, and it takes away the fear for outbreaks of the disease. There is no information about the presence of inoculum and it is therefore not taken in consideration with fungicide applications. The fungicides used are difenoconazol, strobilurines, thiram and captan. Dithianon and tolylfluanide are no longer permitted in the Netherlands and procimidone and tebuconazol have no registration in pear. Difenoconazol and strobilurines are used at maximum 4 times, often alternated with contact fungicides captan or thiram. As much as possible applications are directed at pear scab in combination with brown spot. Firstly, only fungicides with no adverse effect on predatory mites are chosen. Then, the choice of fungicides is mainly based on efficacy against pear scab. Only in those cases were serious outbreaks have occurred or a higher severity occurs regularly, the choice is mainly driven by efficacy of fungicides against brown spot in pear. Price is important but the priority in choice is on efficacy. There are no biological of natural products available with activity against brown spot. There are very few organic pear orchards in the Netherlands due to severe attack of pear scab, which cannot be adequately controlled in the organic system. The organic pear orchards have no problems with brown spot so far. Resistance against fungicides is avoided by a limited number of applications of DMI and strobilurine fungicides and by alternation with contact fungicides. No resistance or reduced efficacy is observed in the Netherlands. The limited number of available fungicides combined with their relatively weak efficacy affects the control of brown spot in the Netherlands.

There are no sanitation practices, such as application of urea or leaf shredding, used in the Netherlands against brown spot in pear. Only recently, it became clear the source of infection is from organic material on the orchard floor. Proof of the efficacy of sanitation practices is urgently needed.

Conference is by far the main cultivar grown in the Netherlands. It is the most profitable pear cultivar, partly due to a good export position. Conference is grown on 75 % of the acreage, Doyenné de Comice with about an acreage of 14 % is second important and all other cultivars like Beurré Alexandre Lucas (3,6 %), Thromphe de Vienne (2,2 %), Beurré Hardy, Verdi, St. Rémy, Gieser Wildeman and Concorde, are mainly grown as pollinators or as remnants in old orchards, in total 11 % of the acreage. Hence, the largest area of pear grown is susceptible to brown spot. The resistance properties are not taken into account when choosing cultivars. Economic considerations are the driving factor. All pears are regularly treated irrespective their difference in sensitivity to brown spot and apple scab, because less susceptible cultivars are often mixed with susceptible ones.
Very much changing from year to year is the occurrence of dead buds caused by *Alternaria alternata* in the Netherlands. Dead buds seem to be present every year. But growers can miss a couple of buds without economic damage. So only when the percentage of dead buds is very high economic damage occurs. A research program is ongoing to control the disease. There are more and more complains about rust caused by *Gymnosporangium fuscum*. Also more problems with *Phytophthora* fruit rot are mentioned recent years.

In conclusion it can be said that the current strategy is not durable with the absence of effective fungicides which could be positioned accurately with warning systems. Fungicide application is the only approach for fruit growers. The last years the problem of brown spots seem to decrease slightly. However, the fear for the disease is still vivid, probably resulting in unnecessary fungicide applications. There is a lack of information about the life cycle of the pathogen *Stemphylium vesicarium*. Also there are no proven measurements of sanitation

practices or cultural methods to reduce the inoculum source in pear orchards. Websites for information for Dutch fruit growers on integrated control of brown spot and other crop protection knowledge are:
http://www.telenmettoekomst.nl/, http://www.dlvplant.nl/ and http://www.fruitconsult.com/. The latter two have restricted areas for clients of consultants with more detailed and actual information on advices based on warning systems.

3.2.4 Belgium

The number of fruit growers in Belgium is around one thousand with average orchards size of 12 ha. The main growing system of pears is single rows with spindle pruned trees at 1500 to 2000 trees per ha. Normally, pears are grafted on quince C, quince A or quince Adams. The weather conditions favour the disease. Infection risk according to BSP-cast is high, although depending on the growth season. The average amount of rain per year during the last 50 years in Sint Truiden in the centre of the main pear growing area was 730 mm per year. The rain can occur during all the months of the year, with June, July and August being the months with the largest amount of rainfall. During the last two decades there seems to be a tendency for more extreme weather conditions with more extreme drought periods and more extreme periods with heavy rainfall. The severity of the disease is depending on the orchard. Most orchards do not have any problem with *Stemphylium*. In most of the orchards were the disease is present, the disease is of minor importance. However, some fruit growers do experience severe losses due to this disease. No cultural methods, like spacing trees or conservative nitrogen nutrition, are used particularly with regard to brown spot control. Irrigation is not common in most regions in Belgium. Irrigation is only common in the Kempen were they grow pear trees on a more sandy soil. The irrigation type most used by the fruit grower is drip irrigation.

In Belgium, the decision support systems BSP-cast and Stemphy (Bodata) are available. Both are recommend as similar results are obtained with both models. The outcome of BSP-cast is free available on the website of the institution during the time of the running research project on brown spot. Stemphy is available for those fruit growers who have a weather station to their disposal. It is unknown if Belgium fruit growers use the Stemphy model. We do not recommend the sporulation models to be used for positioning sprays. The outcome of the BSP-cast model is used by advisers to position fungicide sprays done by the fruit growers. The number of users of the model is unknown. There is an agro meteorological network available in Belgium which is used by the advisers. The number of fruit growers having their own weather station is low. Monitoring of brown spot is only done in the frame work of our brown spot research program. The appearance of the first symptoms and the development of the symptoms is monitored. Especially the orchard with a high infection pressure receive attention. Further more it is recommended that fruit growers monitor their own orchard and reconsider their control strategy when symptoms occur. Based on the monitoring the advice is given to the fruit growers to discuss with their advisors if an alternative control strategy is necessary for example extra fungicide treatments. If infection pressure is high, a weekly preventive schedule is chosen above the use of the infection model. A new hypothesis is that not the inoculum, but the soil type is important for the control strategy proposed to fruit growers. As *Stemphylium* does not seem to occur or occurs less common on a loam soil, advice is given to these fruit growers situated on loam that extra fungicide sprays are not necessary in these orchards. Concerning the inoculum, in those orchards where infection was high in previous season, it is recommended to shred or remove the death leaves of previous season. The mean total number of treatments with fungicides during the total growing season to control all diseases is approximately 15. Twelve of these treatments are done with contact fungicides (dodine, captan, dithianon, mancozeb and thiram). Thiram is the contact fungicide used the most (8 applications). Probably 8 to 10 of the fungicide treatments are positioned against Brown spot although in many cases not only against brown spot. Other fungicides used are the strobilurins including boscalid + pyraclostrobin (Bellis) and difenoconazol. From 2008 also cyprodinil + fludioxonol (Switch) is allowed. With regards to choosing fungicides thiram is used a lot due to its low price, but also because it is considered to be the standard product against brown spot. From 2008 the use of thiram will probably go down because there is a proposal that the maximum number of applications should be reduced to 4. Difenoconazol is used because of its curative action although this curative action seems to be limited. Pyraclostrobin + boscalid (Bellis) and the other strobilurins (kresoxim-methyl, trifloxystrobin) in combination with a contact fungicide are used because they have the best activity against brown spot. Also cyprodinil + fludioxonol (Switch) is a very effective product against brown spot. There are no alternative products used against brown spot in Belgium. Strobilurins are advised to be used in combination with a contact fungicide and the number of application is limited to 4. Pyraclostrobin + boscalid (Bellis) can be used alone as it is already a combination product of two fungicides which have a good activity against *Stemphylium*. From 2008 it is advised to apply one cyprodinil + fludioxonol (Switch) treatment between the strobilurin treatments. Until now there are no resistance problems concerning *Stemphylium* in Belgium. There have been some problems concerning the efficacy obtained with contact fungicides during the previous years. Especially captan seems to fail to control *Stemphylium* during some years. Also the efficacy obtained with thiram fluctuates during different season. The reason why this occurs is currently under investigation. Dithianon is generally considered to have no activity against *Stemphylium*. Comparing a more conventional approach with a modern IPM approach showed in general few differences in the type of fungicides used. However, the fungicides are more accurately applied accoding to warningsystems in the IPM approach.

The control of leaf litter as a sanitation practice is done, but only recommended to fruit growers experiencing big losses at harvest. Research however, points out that grass litter is more important than death leaves and therefore this cultural practice is not recommended to all fruit growers. There are no other sanitation practices used. Sometimes also other fruit growers who have no brown spot do perform sanitation measures. All depends on the fruit grower. The cultivar susceptibility does not influence the use of sanitation practices.

Conference and Doyenne are the most important pear cultivars grown in Belgium. Total pear acreage is 8000 ha with a production of 250.000 tons. Both cultivars are considered as very susceptible for brown spot. There is no resistance management possible with only susceptible cultivars grown. Good quality and export of Conference give a good financial return of investments. More than 90 % is Conference and during last years there is a significantly expansion, about 9% of the acreage is Doyenné plus Durondeau and 1% others. Although there are less susceptable pear cultivars, resistance against Brown spot is not taken into account when choosing new cultivars at this moment, because of economic reasons. More and more new diseases seem to appear. Although common for many years, rust (*Gymnosporangium fuscum*) is occurring more often in pear orchards. The numbers of fruit growers experiencing calyx end rot caused by *Alternaria or Stemphylium botryosum* is rising during the last years. Also side rot (*Phialophora*), *Neofabraea, Phacidiopycnis* and *Coprinus psychomorbidus* infections seems to be increasing during storage.

About the durability of the strategy it noted that there is still room for improvement. Until now there is no preventive action recommended to reduce the infestation. Furthermore research has shown that there is still room for improvement of the infection models. According to the field trials performed during the last 3 years, only 3 or 4 fungicide sprays were really necessary to control the disease. All the other treatments had no supplementary effect. The problems with brown spot in pear are increasing as every year the number of fruit growers noticing the disease is still growing. As a result of the disease the number of fungicide sprays applied to day is higher than 10 years ago. Ranking the measurements as seen by the fruit

growers is: fungicides, sanitation, resistant cultivars. This is also the ranking of advisers at this moment.
The present recommended strategy seems to work, however there is room for improvement. Especially the sensitivity of the pear tree should be investigated and incorporated into the strategy. Furthermore it is still unclear why a 100 % control of the disease seems to be impossible. An other question relates to the latent period of the infection. What factors determine the latent period between infection and expression of the symptoms? Also concerning the local, regional and international spread of disease some mysteries remain.
The strategy is communicated to the fruit growers by means of publications in specialist literature for example Fruitteeltnieuws and by giving presentations to advisers and fruit growers. Also on the webpage www.pcfruit.be the information can be found.

3.3 *Elements of the strategy*

The toolbox of integrated control strategies for brown spot of pear contains a number of elements, i.e. monitoring and decision support systems, cultural methods and orchard management, sanitation practices, non-chemical or environmentally friendly products like antagonists, the use of fungicides and resistant cultivars. The information on the different elements of the strategy is firstly described and then summarised in tables in the next sections.

3.3.1. Monitoring and decision support systems

Monitoring of brown spot in pear orchards helps to alert both the fruit grower and the authorities that possible problems might arise. For brown spot of pear this especially important because it is a new disease which is occasionally responsible for great damage. In the beginning growers didn’t know the symptoms and were “suddenly” confronted with severe rot of fruits. Monitoring of the disease is done in Emilia Romagna, Catalonia and Belgium, but not in the Netherlands (Table 3.3.1.A).
Decision support systems are used in all regions and at the same time further improved. There are two major bottlenecks in the use of decision support systems. The first one is that the life cycle of the pathogen is still incomplete. There are substantial gaps in knowledge on the biology of the overwintering, pathogenicity, latent periods and spread within and between orchards. The second bottleneck is the lack of effective (curative) fungicides to control the disease. Therefore, growers confronted with severe damage in one year, have a tendency to apply superfluous prophylactic fungicide sprays next year without taken into account advices based on a warning system (Table 3.3.1.B).

Table 3.3.1.A. State of the art of monitoring of brown spot in 4 European pear production regions. Figures show the number of regions.

<table>
<tr><td colspan="5">Element of the strategy: Population Monitoring</td></tr>
<tr><td colspan="2" rowspan="2">State of the art</td><td>Ready</td><td colspan="2">Under development</td></tr>
<tr><td>3</td><td colspan="2"></td></tr>
<tr><td colspan="2" rowspan="2">Perspectives for (further) implementation</td><td>Negative</td><td>Neutral</td><td>Positive</td></tr>
<tr><td>1</td><td>1</td><td>2</td></tr>
<tr><td rowspan="2">Obstacles</td><td>None</td><td>Labour</td><td>Economic</td><td>Practical</td></tr>
<tr><td></td><td></td><td>X</td><td></td></tr>
<tr><td colspan="2">Use in practice (% of growers)</td><td colspan="3">75% to 90%</td></tr>
</table>

Table 3.3.1.B. State of the art of the use of decision support systems for brown spot in 4 European pear production regions. Figures show the number of regions.

<table>
<tr><td colspan="5">Element of the strategy: Decision support systems</td></tr>
<tr><td colspan="2" rowspan="2">State of the art</td><td>Ready</td><td colspan="2">Under development</td></tr>
<tr><td>4</td><td colspan="2">4</td></tr>
<tr><td colspan="2" rowspan="2">Perspectives for (further) implementation</td><td>Negative</td><td>Neutral</td><td>Positive</td></tr>
<tr><td>0</td><td>0</td><td>4</td></tr>
<tr><td rowspan="2">Obstacles</td><td>None</td><td>Labour</td><td>Economic</td><td>Practical</td></tr>
<tr><td>X</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Use in practice (% of growers)</td><td colspan="3">Ranging from few growers (Netherlands) to almost all of them (Emilia Romanga and Catalonia).</td></tr>
</table>

3.3.2. Cultural methods and orchard management

Cultural practices to control fungal diseases generally deal with several aspects. Better aeration within the canopy to promote faster drying of leaves and fruits is an important method. This can be done by spacing trees more widely or summer pruning. The conservative use of nitrogen is sometimes done. It reduces the number of young often susceptible leaves. Finally, strategies to improve soil quality and soil activity to promote healthy root system and to improve leaf degradation are used. However, none of these orchard management practices play a role in all regions with problems of brown spot of pear.

3.3.3. Sanitation practices

Two types of sanitation practices are used against brown spot of pear. These are the use of urea and leaf shredding. It is known that urea promotes leaf degradation. For apple scab it is known that urea also prevents formation of ascospores in overwintering leaf tissue. This is not proven for brown spot in pear. Leaf shredding helps to promote leaf degradation. This method is directed against overwintering stages of the disease in fallen leaves of pear. However, although part of the population might hibernate in this way, recent information shows that a substantial part of the population might overwinter in the asexual phase on grasses and dead organic material. Non-the-less, leaf shredding is used in some regions.
Sanitation practices are used on a limited scale in all regions, mainly because the effectiveness is doubted (Table 3.3.3.)

Table 3.3.3. State of the art of the use of sanitation practices against brown spot in 4 European pear production regions. Figures show the number of regions.

<table>
<tr><td colspan="5">Element of the strategy: Sanitation Practices: urea applications and leaf shredding</td></tr>
<tr><td colspan="2" rowspan="2">State of the art</td><td>Ready</td><td colspan="2">Under development</td></tr>
<tr><td>4</td><td colspan="2">0</td></tr>
<tr><td colspan="2" rowspan="2">Perspectives for (further) implementation</td><td>Negative</td><td>Neutral</td><td>Positive</td></tr>
<tr><td>0</td><td>4</td><td>0</td></tr>
<tr><td rowspan="2">Obstacles</td><td>None</td><td>Labour</td><td>Economic</td><td>Practical</td></tr>
<tr><td></td><td>X</td><td></td><td></td></tr>
<tr><td colspan="2">Use in practice (% of growers)</td><td colspan="3">0 % to 5 % (efficacy not proven)</td></tr>
</table>

3.3.4. Non-chemical control methods

Non-chemical control methods against brown spot in pear are not presently used in Europe. Some scientific work is done with antagonists as sprays on the orchard floor, to reduce the inoculum. But this method is not yet ready for introduction into practice (Table 3.3.4).

Table 3.3.4. State of the art of the use of non-chemical control methods against brown spot in 4 European pear production regions. Figures show the number of regions.

Element of the strategy: Non-Chemical Control Methods				
State of the art		**Ready**	**Under development**	
		0	X	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
			X	
Obstacles	**None**	**Labour**	**Economic**	**Practical**
Use in practice (% of growers)		0 % still under scientific development		

3.3.5. Chemical control methods and resistance management

Fungicide application is by far the most important control method against brown spot in pear. Primarily protective fungicides are used like thiram and captan. (Table 3.3.5.A). Even in a tight schedule of applications once in five days these products cannot provide complete control under conducive conditions for the disease. More effective fungicides belong to the groups of dicarboximides, strobilurines and some others. However, fungicides from these groups are very vulnerable for development of resistance. Happily, the majority of fruit growers and advisors are aware of the danger of resistance. Non-the-less, resistance was demonstrated against dicarboximides in Emilia Romagna. In all regions fungicides are alternated with protectant fungicides to avoid further development of reduced efficacy (Table 3.3.5.B).

In all regions, but especially, in the cooler and wetter regions in Belgium and the Netherlands, often the same fungicides are used to control pear scab in the same time. Timing of fungicides is primarily directed against pear scab during dangerous periods often occurring in spring in most regions. On the contrary, from June onwards, most sprays in southern countries are primarily directed and timed against brown spot in pear.

Table 3.3.5.A. State of the art of the use of protectant fungicides in 4 European pear production regions. Figures show the number of regions.

Element of the strategy: Chemical Control Methods: use of protectant fungicides				
State of the art		**Ready**	**Under development**	
		4	0	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
		0	0	4
Obstacles	**None**	**Labour**	**Economic**	**Practical**
	X			
Use in practice (% of growers)		100%		

Table 3.3.5.B. State of the art of the use of alternation of protectant fungicides with systemic fungicides in 4 European pear production regions. Figures show the number of regions.

Element of the strategy: Chemical Control Methods: alternation of fungicide groups				
State of the art		**Ready**	**Under development**	
		4	0	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
		0	0	4
Obstacles	**None**	**Labour**	**Economic**	**Practical**
	X			

Use in practice (% of growers)	90%

3.3.6. Resistant cultivars

Pear cultivars range in their susceptibility for brown spot of pear. The majority of pear cultivars grown in Europe, such as Conference, General Leclerc and Abbè Fetel are very susceptible for brown spot. Some cultivars are fairly susceptible, like Doyenné de Comice and some are nearly resistant such as Kaiser William. Cultivar choice is also to day mainly driven by economic reasons. Since fungicides are relatively cheap, the susceptibility for brown spot is not the primary factor for choice. Only in Catalonia, the very susceptible cultivar Passe Crassane, is slowly replaced by slightly less susceptible other cultivars. A bottleneck is that there are no good tasting and economic interesting cultivars of pear resistant to brown spot of pear. Moreover, there is no European breeding program on resistance for this disease.

Table 3.3.6.A. The use of resistant cultivars for brown spot in 4 European pear production regions. Figures show the number of regions.

Element of the strategy: Use of resistant cultivars				
State of the art		**Ready**	**Under development**	
		0	0	
Perspectives for (further) implementation		**Negative**	**Neutral**	**Positive**
		4		
Obstacles	**None**	**Labour**	**Economic**	**Practical**
			X	X
Use in practice (% of growers)		2 %, no good resistant cultivars are available		

3.3.7. Emergence of secondary diseases

In Emilia Romagna recent monitoring proved the widespread appearance of Valsa canker or Cytospora canker which is caused by two species of fungi, *Leucocytospora cincta* and *Leucocytospora leucostoma*. However other source report V*alsa ceratosperma* (Tode ex Fr.) as the causal agent. In Catalonia no new diseases are observed in pear. In the Netherlands and to a lesser extent also in Belgium, very much changing from year to year is the occurrence of dead buds caused by *Alternaria alternata*. Dead buds seem to be present every year. But growers can miss a couple of buds without economic damage. So only when the percentage of dead buds is very high economic damage occurs. A research program is ongoing to control the disease. Although common for many years, rust (*Gymnosporangium fuscum*) is occurring more often in pear orchards in these countries. Also more problems with *Phytophthora* fruit rot are mentioned recent years in the Netherlands. And in Belgium the numbers of fruit growers experiencing calyx end rot caused by *Alternaria or Stemphylium botryosum* is rising during the last years. Also side rot (*Phialophora*), *Neofabraea, Phacidiopycnis* and *Coprinus psychomorbidus* infections seems to be increasing during storage.

It seems difficult to attribute the increased presence of the mentioned diseases to a changed fungicide programme. May be it is a combination of more factors such as a more widely spread alternative host for rust, transport of inoculum and other factors.

3.4 *Durability of the strategy*

In all regions it is concluded that the control of brown spot on pear is very much dependent on fungicide use. The situation is stable, but regions think differently about the durability of the situation. Especially in Emilia Romagna and Catalonia the situation is critical as problems will occur in future due to banning of products due to enforcing the EU 91/414 regulation. Another important factor is the high number of treatments and consequently, the high level of residues. Supermarkets more often demand lower residue levels and of fewer pesticides than legally permitted and safe for human health. This will further limit the use of fungicides. The result is a substantiated fear that the disease will not be controlled in future. Especially so, because the disease is new and there are substantial gaps in knowledge, which affects the tools for development of more sustainable non-chemical control methods. It can be concluded that the current strategy is not durable.

3.5 *Bottlenecks (social, economic, technical)*

For durable control of brown spot in pear three main bottlenecks can be identified. These are the availability of effective fungicides (technical), the fear of fruit growers for damage (social) and the gaps in knowledge of the disease (technical). The fear of fruit growers for damage of the disease might partly be taken away by improving decision support systems and further implementation of these systems in practise. In all regions, there are adequate systems for spreading new information about the disease among end users. However, new information about the disease is gathered in relatively small regional projects. And progress in filling up gaps in knowledge of the life cycle is relatively slow. Consequently the development of sustainable cultural or sanitation practices is slow. The registration of products with generally regarded as safe profiles (GRAS products) and antagonists is tedious and costly in the European union. This is a substantial bottleneck for companies with effective products who will never be able to make profits on these products because of too high registration costs.

3.6 *Conclusions*

Based on the collected information the following conclusion can be drawn:

- Population monitoring of brown spot is important and done in all investigated regions except the Netherlands.
- Decision support systems are used in all regions.
- Further improvement of decision support systems is ongoing in all regions.
- No cultural practices, such as more widely spacing trees and open canopies, are used in any region in Europe to prevent brown spot of pear.
- The use of urea as a sanitation practice is used only in Catalonia by 50 % of the growers.
- The use of leaf shredding is hardly used. Only fruit growers with severe damage in the previous year apply leaf shredding.
- Non-chemical control methods against brown spot are not used in Europe.
- Protectant fungicide applications are extensively used, partly driven by fear.
- Alternation of fungicide groups is used in all regions.
- The variability between cultivars in their susceptibility towards brown spot in pear is not used. Economic factors completely dominate the choice of cultivar.
- Major bottlenecks in a durable control of brown spot are:
  - lack of effective fungicides
  - lack of knowledge of the biology of the causal fungus *Stemphylium vesicarium*, such as pathogenicity, overwintering and latent period
  - fear by fruit growers for severe damage.

- Pesticide residues in fruits have been signalled almost unanimously as the major market concern.

4 Survey of the state of the art of apple scab integrated control strategies

4.1 *Questionnaire and regions covered*

The questionnaire (Annex 1.1.3.) was sent to scientist and/or Plant Protection officers from 9 European apple and pear growing areas. Personal interviews were also carried out in some cases. The selected regions are representatives of Northern and Southern climates, and active Integrated Pest Management programs have been developed and are applied in them. The selected regions were: Emilia Romagna, Poland, Trentino and South Tyrol (Italy), Lake Constance (Germany), Lake Constance (Switzerland), Netherlands, Rhône Valley (France) and Lleida (Spain). No information has been obtained from Emilia Romagna and Poland.

4.2 *Description of the strategy per regions*

4.2.1. Lake Constance, Germany

Interviewed: Martin Trautmann, Ravensburg (KOB Extension officer) and Peter Triloff, Friedrichshafen (MABO Extension officer)

General information about the region

The apple orchards of the region cover a total area of 8.000 ha, cultivated by 1.500 different growers. The sizes range from one to forty hectares, the trend point toward fewer but larger orchards. Integrated pest control is used in the mayor part of the orchards. Only about fifty orchards, with a total area of approx. 450 ha, are organic, but organic apple production is expanding.
So far, approx. 15% of the orchards are covered with hail nets, the trend is positive. Meadow trees of the region are not commercially used. In this region, different extension officers are consulting, thus, the individual growers get information about various control strategies, which in some cases may result in some confusion.

Control strategy of apple scab

Weather conditions

The weather conditions are favourable for apple scab. The amount of rain range from 700 mm per year in the western part of the region up to 1.400 mm in the eastern part. Max. 5% of the growers irrigate their orchards, mainly with sprinklers.

Cultural methods and orchard management

MABO: High prioritized is the purchase of good material from the tree nursery, i.e. trees with a restricted growth of the shoot. Problematic parcels sometimes are treated with a growth regulator (prohexadione-Ca (Regalis)). Important is a control strategy with minimal side effects to the earthworm, e.g., restricted use of copper.
KOB: No cultural method is done especially in regard to the prevention of apple scab. The guidelines of the integrated or organic orchard practices are complied.

Decision support system

The extension officers use information from RIMpro, spore traps and weather stations to write their reports about infection periods, recommendations for treatments, etc. One of the extension officer (Mr. Triloff) also includes data about the increment of apple leave area. This allows the prediction of the effective period of protective fungicides. The reports are communicated to the growers by fax or by phone. Each extension officer sends his report to approx. 400 growers. The reports are edited about three times per week during the season. Growers use their own weather observations and websites of different weather forecasts to supplement the recommendations.

Monitoring
KOB: No precise monitoring is made, growers observe their orchards during cultivation practices. The observance of damaged fruits at harvest influences the control strategy of the following year.
MABO: A monthly monitoring is recommended, from the primary infection till the leaves fall. So far, only about 10% of the growers (and depending on the severity of the disease) carry out monitoring, but there is a potential for improvement.

Fungicides
KOB: Because of the high severity of the disease, approx. twenty-five treatments are made. In good years, like 2003, eighteen treatments can be enough. Due to fungicide resistance problems, the control strategy lately was changed from a protective and curative strategy towards an only protective strategy. Dithianon (Delan) is used as standard protective fungicide alone and in mixtures. Other permitted fungicides: mancozeb (Dithane), captan (Malvin, Merpan), penconazol (Topas), trifloxystrobin (Flint), kresoxim-methyl (Discus), dodine (Syllit), cyprodinil (Chorus), pyrimethanil (Scala), pyrimethanil + fluquinconazole (Vision), flusilazol (Benocap), myclobutanil (Systhane). For full-blossom spraying, trifloxystrobin (Flint) is used, but after the primary infection, only protective products are sprayed. Tolylfluanid (Euparen) is not permitted anymore. It left a big gap as fungicide used for final treatment. In autumn, if the risk of an infection is high, trifloxystrobin (Flint) is sprayed, but it is recommended to use it as less as possible, to maintain its effectiveness. The price of a product is not the first criteria used while choosing the fungicides. Mode of action and effectiveness are the reasons for choosing the fungicides.
MABO: Because of resistance problems, no curative fungicides are used against scab anymore, therefore the treatments are made exclusively with protective fungicides (Delan WG, Merpan, copper). Three different control strategies are recommended, depending on the percentage of infected shoots and fruits in the autumn of the previous year:
1. Less than 10% of infection: treatments only in severe infection periods.
2. 11% - 30% of infection: treatments in every infection period.
3. More than 30% of infection: treatments in every infection period plus sanitation with “Elise”, a machine used to remove the leaf litter present in the orchard.

The number and the interval of treatments depend on the severity of the disease pressure and range from two to three times of spraying a week in bad years to a single treatment every three weeks in good years. Kresoxim-methyl (Discus) and trifloxystrobin (Flint) are used only against mildew and sooty blotch (Regenflecken). The inoculum present at the scale of a group doesn’t influence the strategy of a single grower, because apple scab is an orchard specific problem. Choice of fungicides is not influenced by the price, important are effectiveness and mode of action. Only environment friendly products are permitted by the government. Resistance management is made by having a preventative strategy, by alternation of products with different mode of action and by preventing mixtures of fungicides in the tank.

Resistance occurs against sterol synthesis inhibitors flusilazol (Benocab) and anilinopyrimide (Chorus, Scala, Vision). Resistance has been proven in the laboratory.

Sanitation

KOB: Sanitation is important, especially in orchards with a high severity of the disease. Sometimes urea or/and lime nitrogen (Kalkstickstoff) are sprayed. Leaf litter is mulched and sometimes removed from the orchard with the machine "Elise". "Elise" can be hired by the growers. So far, there are two "Elises" in the region.
MABO: Sanitation becomes more and more important. The extension officer promotes it strongly. Traditionally, urea was sprayed, but the trend is negative. Now, mulching of the leaf litter becomes more popular. Approx. 5% of the growers use "Elise". The trend for the use of "Elise" is positive.

Resistant cultivars
Topaz is grown in the main part of the organic orchards. In integrated orchards, Topaz covers a small area. Topaz has potential, especially for growers doing a direct commercialization. So far, there is a lack of resistant cultivars with good qualities for the market.
It is recommended to treat Topaz only during the primary infection, one to five times (depending on the severity of the disease in the orchard). The reason for the treatment is the lowering of the selection pressure for possibly occurring resistant scab populations. So far, no resistance breakdown of *Vf* resistance has been observed.

Knowledge gaps - Perspectives
KOB:

- How much are the conidia involved in the primary infection? (conidia surviving the winter.)
- If an ascospore doesn't germinate during the period of the primary infection, for how long is it still able to germinate?

MABO:

- Epidemiology during summer. Little is known about the favourable conditions for the secondary infections.
- Conditions during the winter influencing the development and maturation of ascospores. Mr. Triloff is working on this objective. Among other things, temperature and humidity are measured in the leaf litter.

Conclusions
MABO: For fifteen years, the strategy has been improved constantly. Much is known about the process and control of the primary infection, questions remain about the secondary infections. Scab problems are increasing due to the climate change implicating increased humidity in autumn. If apple scab is well controlled during the primary season, less fungicides are sprayed during the remaining season. However, this success may lead to the increase of problems associated with fungi previously controlled by the saved treatments.

Varia
KOB: Main objectives are the increment of sanitation practices and the maintenance of the effectiveness of trifloxystrobin (Flint) by using it as little as possible, thus, it is very important to control scab in primary infection to avoid the use of trifloxystrobin for the final treatment.
MABO: The control of apple scab should focus on non fungicides strategies. Good sanitation practice is the most important part of the control strategy. Breeding of resistant cultivars with good qualities for the market must become a main objective for the future. Treatments with fungicides have to be well directed; sometimes it is a matter about catching the right hour for spraying. The theoretical goal is a control strategy practically without fungicides. The basic know-how is available, but there are still some obstacles in the implementation, e.g., well directed spraying, monitoring and sanitation are not enough taken in account by many of the growers.

4.2.2 Lake Constance, Switzerland

Interviewed: U. Müller, Extension officer Canton Thurgau; R. Hollenstein, Extension officer Canton St. Gallen

General information about the region

Canton St. Gallen: In St. Gallen, meadow fruit trees (high stem trees) are a common and appreciated element of the landscape. There are approx. 140.000 meadow apple trees. About half of them are commercially used, thus treated with pesticides. Intensive apple orchards with dwarfing rootstocks cover a total area of 205 ha, cultivated by 150 different growers. Integrated pest control is used in approx. 88% of the orchards, the residual 12% are organic.

Canton Thurgau: The apple orchards of the region cover a total area of 1.400 ha, cultivated by 500 different growers. The sizes of the orchards range from one to twenty hectares. Integrated pest control is used in approx. 93% of the orchards, the residual 7% are organic. The region is subdivided in twenty-four cycles. The growers of each cycle have their own meetings, three to four times during the season.

Control strategy of apple scab

As the control strategies applied in the two Cantos resulted to be similar the information obtained as been summarized in a single report.

Weather conditions

The weather conditions are favourable for apple scab. The amount of rain of approx. 1200 mm per year is evenly distributed. The weather conditions during the main infection period are different from year to year. In the last years, dry periods occurred more often.

Cultural methods and orchard management

Important is a good physiological balance of the apple trees. Time and effort is invested in a proper pruning and the fertilisation is well adapted to the demand of the trees. To keep a good soil activity, the distribution of compost in the orchards becomes more and more popular and treatments with copper are restricted to the minimum. Irrigation is increasing (mostly drip) due to dry years like 2003 and 2006.

Decision support system

The extension officers use information from weather stations, spore traps, forecasts from the federal research station Agroscope, etc., to write their reports about infection periods, recommendations for treatments, etc. The extension officers communicate their reports to the growers of their region, mainly by fax and phone. Most of the growers take out a subscription. The growers rely on the recommendations of the extension officers and supplement them with own weather observations and experiences. Up to three reports are communicated to the farmers weekly during the season.

Monitoring

Monitoring is not made as a routine practise, but the growers "check" their orchard during the works and as soon as they observe a severe scab problem, they call the extension officer of their region, to solve the problem with his help.

Fungicides

Number and interval between treatments depend on infection periods. About twelve treatments with protective and curative fungicides are made. Fungicides used: dithianon

(Delan), captan, folpet, dodine, sterol synthesis inhibitors, anilinopyrimidine (Vision, Chorus, Frupica, Scala), strobilurine (kresoxym-methyl (Stroby), trifloxystrobin (Flint)). Alternation of products with different modes of action is used to prevent fungicide resistance development and is complied by all of the growers. When choice of fungicides is made, in big orchards the price can play a role but the effectiveness of the fungicide (at best with additional effects against other fungi) is the most important property considered. Only environmentally friendly products, permitted by the government, are used. Naturally occurring substances, i.e. sulphur and copper are also used. So far, no fungicide resistance has been observed. If a grower suspects a resistance problem, he calls the extension officer. Together they analyse the situation. Till now, loss of effectiveness of fungicides was diagnosed as failures of good agricultural practice, e.g. mistakes in application techniques or wrong amounts of spray mixtures. Application of reduced doses to save environmental pollution is hardly done because of fear for development of resistance.

Sanitation

Leaf litter is mulched by most of the growers. In autumn, a minor part of the growers spray urea. Apples left behind in the orchards after harvest and heaps of leaf litter stuck near fences are removed or mulched. If growers notice an increased scab problem at harvest, more attention is paid to a proper sanitation.

Resistant cultivars

Resistant cultivars are grown in about half of the area of the organic orchards. About half of them are Topaz and the other half are a lot of different, minor cultivars, e.g., Retina, Ariwa, Rewena, GoldRush, Resista, Ecolette, etc. Resistance properties are the main reasons when choice of cultivar is made for organic orchards. Growers are experimenting with the different cultivars. For commercial use, some of the cultivars listed above may disappear again. In orchards using integrated pest control, Topaz (and no other resistant cultivar) is grown in a very minor part of the area. Topaz is grown because there is a market for it.
The extension officers recommend four to eight treatments of the scab resistant trees, in integrated and organic orchards. The reasons for the treatments are resistance management and control of secondary fungi. So far, no resistance breakdown of *Vf* resistance (e.g. Topaz) has been observed in commercial orchards.

Knowledge gaps - Perspectives

Knowledge gap: An investigation of the impact of hail nets would be of interest. Expected is an increased scab problem in orchards covered by hail nets, but so far, the experience was rather a decrease of scab.
Negative perspective: A main concern is the withdrawal of permitted pesticides by the government without replacing them by new ones, thus the line-up of permitted fungicides diminishes.
Positive perspective: Breeding of resistant cultivars with good qualities for the market seems to be a good solution for the future.

Conclusion

There is a flow of information between the federal research station Agroscope, the extension officers and the growers. Trees possessing a good physiological balance, well directed spraying of fungicides and mulching of the leaf litter, keeps the severity of the disease on an acceptable low level. In spite of the favourable weather conditions for apple scab, so far, the disease is under control. Over the past years, the severity of the disease was constant or even a bit decreasing due to improvements in application techniques and the use of smaller trees with less growth of the shoots.

4.2.3 Lleida (Catalonia), Spain

Interviewed: Jaume Almacellas Gort, Plant Health Service, DAR – Generalitat de Catalonia; and Juan Pedro Marín Sánchez, Marta Coma, Universitat de Lleida

General information about the region

The apple orchards of Lleida cover a total area of 9.381 ha and belong to 8.165 growers. The average size of an orchard is 2 ha per grower and 1 ha per orchard plot. The region is subdivided in areas. The growers of the areas are led by advisors and the advisors are coordinated by the Plant Health Service. The Plant Health Service and the advisors have weekly meetings together. Material or means to communicate strategies to the farmers: advisors, leaflets, meetings, workshops, SMS mobile phone messages, etc. Relevant websites:
http://www.gencat.net/darp/c/camp/avisfit/cavindex.htm
http://www.ruralcat.net/ruralcatApp/agrometeo/html/agrometeo.htm?gencat=2

Control strategy of apple scab

Weather conditions

The weather normally is not especially favourable for apple scab. The region is warm and dry during the growing season. The amount of rain is less than 400 mm per year in the fruit tree growing area. From 1990 till 2006 there was an average of five to six episodes of heavy rain in the period from April till June. Nowadays it is less (climate change?) with an average of five episodes. The importance of apple scab is decreasing.

Cultural methods and orchard management

Conservative nitrogen nutrition is complied but the main reason is to rationalise the use of the nitrogen. All of the orchards are irrigated, in general by flooding. Drip irrigation is used occasionally but its use is increasing.

Decision support system

Information is shared between growers, advisors and the Plant Health Service. The Plant Health Service sends area-specific recommendations for the control of apple scab to the growers via websites, press, e-mails and sms. To predict the risk of infection, weather conditions (temperature and hours of wetness) and Mill's infection curves are used. The system is available on the website of the agrometeorological net of DAR. The system works automatically without human action. Agrometeorological stations regularly send their data and the prediction is done by computer software. The programme issues a prediction of the risk at real time and also meteorological parameters like temperature, humidity, time of wetness, etc. There is no statistic about how many growers use the system to plan their treatments.

Monitoring

Advisors perform monitoring in the orchards during the "susceptibility period" to verify the predictions and the decisions taken aiming the control of the disease. The parameter observed is normally the percentage of fruits affected by apple scab. According to the results of the predictions and the monitoring, the growers decide if further control measures are necessary or not.

Fungicides

Spraying is done according to the treatment recommendations. The average number of treatment recommendations is 5,5 per growing season. In the practice the number of applied

treatments can be higher. Depending on the efficacy of treatments and the overlapping of the infection periods, one to three treatments may occur per treatment recommendation. The most used fungicides are: bitertanol, captan, ciproconazole, diniconazole, flusilazole, hecaconazole, kresoxym-metil, miclobutanil, tiram, trifloxistrobin and ziram. The reasons of choice of fungicides are: 1. activity (preventive, curative), 2. adaptation to climate and phenological state, 3. price, 4. side effects, 5. environmental or human health considerations. Alternative products are not used. At the moment there are no problems with the availability of different fungicides. The list of fungicides is sufficient to control the disease.
In general treatments are made with mixtures consisting of organic (multisite) and systemic (unisite) fungicides. If not, the different fungicides are sprayed in alternation. Resistance problems are occasionally reported and are mainly due to particular practices of the grower, such as the frequent use of a single fungicide. Resistance tests are done by chemical companies but normally the results are not communicated. Sometimes fungicide resistance is suspected but it was never experimentally proved. Reduced efficacy so far was caused by incorrect application in timing.

Sanitation
In autumn urea or copper is sprayed over the trees. This is generally successful and accepted as a good practice to manage apple scab. The percentage of growers who spray urea or copper is around 20 to 40%. More than 90% of the growers shred the leaf litter together with the trimmed timber. Leaf shredding is a routine practice but the application of urea or copper is done only when apple scab problems occur and mainly in susceptible cultivars.

Resistant cultivars
Most of the cultivars are susceptible. Resistance properties are not relevant while choosing the cultivars. Nowadays growers take more risks to introduce high value but susceptible varieties in their orchards e.g. Pink Lady® or Fuji. The few scab resistant cultivars are not treated with fungicides in regard to apple scab, but there are other diseases, like powdery mildew, that involve fungicide treatments. Resistance breakdown sometimes was observed (or supposed to be) but it has never been proved. So far, new diseases did not appear. Cultivars and their percentage of acreage: Golden Delicious 37%, Golden Smoothee 7%, Fuji 6%, Gala Group (not specified) 5%, Granny Smith 4%, Golden Reinders® 4%, Mondial Gala 4%, Galaxy 4%, Red Chief 4%, Brookfield Gala 3%, Early Red One 2%, Golden Supreme 2%, Top Red Delicious 2% and the rest of the varieties descending in %.

Knowledge gaps - Perspectives
Knowledge gaps: study of the disease in regards to local conditions to improve the treatment recommendations. The Mills' curves have to be adjusted to local conditions and the decision support system has to be validated.
Perspectives: currently the ranking of the different approaches used to control scab are for the growers and advisors: 1st fungicides, 2nd sanitation and 3rd resistant cultivars. The strategy of future of the Plant Health Service foresees: 1st sanitation, 2nd fungicides and 3rd resistant cultivars.

Conclusion
In general, the strategy is durable. During the last five years, scab problems decreased probably due to the unfavourable weather conditions for apple scab. A negative economical consequence is the trend of introducing more and more high value but susceptible cultivars.

4.2.4 South Tirol (Italy)

Interviewed: Dr. Klaus Marshall, Dr. Roland Zelger, Research Centre Laimburg

General information about the region

The apple orchards of South Tirol cover a total area of 18.000 ha and belong to 9.000 different owners (average: 2 ha per owner). Some of the owners employ growers for cultivation practices. Only about 5% of the orchards are larger than 10 ha, the perspective of larger orchards is neutral. The growers are well organised in the institution called Beratungsring. The Beratungsring includes about 4.000 growers (and a total area of 12.000 ha) and 35 extension officers. The region is subdivided in districts. Each district is consulted by approx. 4 extension officers. They meet with the growers of their district once every two weeks during the season and visit the orchards. Every week all of the extension officers of South Tirol have a meeting together. In winter there is a meeting of the extension officers and the research centre Laimburg. Even though not every grower is member of the Beratungsring, about 90% of the growers get their information about recommendations of treatments, etc. The Beratungsring communicates the information in newsletters, by phone, sms, internet and in brochures. Information is also spread by personal contacts.
Integrated pest control is used in 90% of the orchards. 5-6% of the orchards are organic (total area of 1.000 ha). The trend for organic orchards is positive, particularly for the more dry districts in the western part of the region.
There are almost no meadow trees in the region.

Control strategy of apple scab

Weather conditions

The amount of rain is 750 mm per year. The rain periods are short and apart from each other. Thus the conditions are not favourable for apple scab. Only about every 10 – 15 year, there is a year of a high severity of the disease, probably due to the coincidence of different factors.
About 95% of the orchards are irrigated by sprinklers, the main reason is frost protection. Additionally 40 – 70% of the orchards have drop irrigation.

Cultural methods and orchard management

Sometimes the growth regulator Regalis is used, but the trend is negative. Fertilisation is well directed to the demand of the trees. In autumn, approx. 90% of the growers spray urea.

Decision support system

Almost all of the growers get the information of the Beratungsring. Among others, data from the 120 weather stations and different spore traps are used for predictions of infection periods and recommendations about treatments. RIMpro is rarely used.

Monitoring

A precise monitoring is made by the extension officers together with the growers after the primary infection period. Control strategy during the summer is according to the results of this monitoring.

Fungicides

The threshold for infected shoots after primary infection period is 2% for very susceptible cultivars (Golden Delicious, Braeburn, Cripps Pink, etc.) and 5% for less susceptible cultivars (Elstar, Gala, Idared, etc.). Below the threshold a treatment with curative fungicides is recommended only if very susceptible cultivars without a film of fungicide stay wet longer than two days. Above the threshold intervals of treatments are according to rain periods, fruit

growth and the degradation of the fungicides. The fungicides used are: captan, dithianon, dodine, mancozeb, fluazinam (Ohayo), difeonoconozol (Score), pyrimethanil (Scala), cyprodinil (Chorus), trifloxystrobin (Flint), kresoxym-methyl (Stroby), pyraclostrobin + boscalid (Bellis), copper hydroxice. The most used fungicide is dithianon (Delan). Anilinopyrimidine (Chorus, Scala) are used before blossom, sterol synthesis inhibitors (difenoconozol) are used after blossom. Alternative products: lime sulphur (only in organic orchards), copper, sulphur.
In average 12 to 15 treatments are applied per year against apple scab. Mildew and Alternaria are treated separately. Resistance management is complied by all of the growers by alternation of products with different mode of action and by limitation of treatments according to the results of the monitoring after the primary infection period.
So far, no resistance against fungicides occurred. Loss of effectiveness of fungicides has never been proven to be due to fungicide resistance development.

Sanitation
Leaf litter is mulched together with the trimmed timber as a routine practices complied by approx. 90% of the growers. Due to the low incidence of the disease, sanitation is reputed not important. Experiments were made to prove the effectiveness of sanitation, but the severity of the disease was too low to really prove an effect. Nevertheless approx. 90% of the growers spray urea in autumn.

Resistant cultivars
Resistant cultivars are not relevant. Even in organic orchards, resistant cultivars cover less than 1% of the area (totally 25 – 30 ha). The mainly used resistant cultivar is Topaz, however also few GoldRush and Florina are grown. No *Vf* resistance breakdown has been observed.

Knowledge gaps - Perspectives
The current major knowledge gap is the precise interpretation of the RIMpro and PAD values.

Conclusion
Due to few and short rain periods (and restricted shoot-growth of the trees), apple scab is a minor problem in South Tirol. However, treatments with fungicides are made, because fewer or no treatment at all are considered be too risky for the growers. There are other plant pathology problems bigger than apple scab, e.g. *Alternaria*, *Phytoplasma mali*, fire blight, sooty moulds.

4.2.5 Trentino, Italy

Interviewed: Luisa Mattedi, Istituto Agrario di San Michele all'Adige

General information about the region
The 3.577 apple orchards of Trentino cover a total area of 11.000 ha. The main part of the growers own 2 - 4 ha. A minor part of the orchards are organic (75 orchards with a total area of 241 ha). There are some meadow trees used commercially.

Control strategy of apple scab
Weather conditions
The yearly amount of rain is approx. 900 mm. In the last years it was less, i.e. 600 – 700 mm. The incidence of the disease is low. 2001 was the last year with an increased apple scab problem. In orchards located on the flanks of the valley (upper elevations), the secondary infection is more severe than in the plane of the valley.

Cultural methods and orchard management
In spring, all of the growers mulch the leave litter together with the trimmed timber and 10% of the growers spray urea.
In autumn, about 50% of the grower do a mulching and 90% of the growers spray urea and copper, mainly to promote leave fall and as fertilisation. The use of copper causes less problems in this area due to the high amount of organic material in the soil absorbing the copper.

Decision support system
About 40 extension officers are consulting in this region. The information provided by the extension officers reach practically all of the growers. Growers don't have to pay for the service. Information is communicated by phone (callable messages), e-mail, teletext, notice boards and personal contacts. Extension officers use spore traps, weather stations, RIMpro and monitoring on shoots and leaves to make forecasts about infection periods and recommendations about treatments etc. A website is under development. PAD is used only for experimental purpose. Investigations are made to find out which value of RIMpro can serve as threshold. Growers have to cooperate because their parcels are small and close to each other, thus, they may infect each other.

Monitoring
Monitoring is performed to verify the control strategy and to decide if sanitation has to be done. In general, three to five monitoring on shoots and leaves are accomplished by the extension officers: the first monitoring is done at the end of the primary season, one or two monitoring are done during summer, one monitoring is done at harvest (on fruits) and the last monitoring is done in October. The October threshold is 10% of infection (10 infected shoots out of 100 shoots). Below the threshold, the situation is considered good, thus sanitation is not explicitly recommended. Above the threshold, more attention is paid to the disease and sanitation is recommended. But this situation did not occur for a long time, 2001 was the last year with an increased scab incidence. Growers only look after fruit damage. If they observe a problem, they contact the extension officers.

Fungicides
The base of the strategy is a well-target preventative spraying program. As far as possible, treatments are done before rainfall. After an intense rain or after a period with increased growth of the shoot followed by rain, a curative treatment is recommended. If no infection period is in sight, two weeks without any treatments at all can occur. The total number of

treatments ranges between 10 - 12 times at minimum and 20 - 24 times at maximum. Alternative products like sulphur, lime sulphur (only in organic orchards) and copper are used.
Resistance management is accomplished by alternation of products with different modes of action and is complied by all the growers. Curative fungicides (anilinopyrimidine, SSI) are used in mixtures with preventative fungicides, mainly with dithianon (Delan).
So far, no fungicide resistance occurred (neither to strobilurins).

Sanitation
Due to the low incidence of the disease, so far, it was difficult to find out if sanitation is effective. Treatment with urea and mulching of leaf litter together with the trimmed timber is done as routine practice.

Resistant cultivars
Resistant cultivars are not relevant. Even in organic orchards, resistant cultivars cover far less than 1% of the area. The few resistant cultivars are treated approx. 8 times with sulphur and lime sulphur, mainly because of the mildew. So far, no resistance breakdown has been observed. Tolerant cultivars probably have bigger potential then resistant cultivars to be grown in this region in the future.

Knowledge gaps - Perspectives
No evident knowledge gaps.

Conclusions
So far, the strategy is durable. Fluctuations in successful control occur due to yearly different weather conditions, shoot growth etc. At the moment, other plant pathology problems (e.g. *Alternaria*, *Phytoplasma mali*) are more severe than apple scab.

4.2.6 The Netherlands

Interviewed: Henny Balkhoven, Fruitconsult

<u>General information about the region</u>
Roughly about 2.000 growers with apple and pear, from which about 1.000 are professional growers. The total area is about 16.000 ha; the average size is about 8 ha, ranging from 2 to more than 100 ha. About 95 percent is growing pomefruit according to IPM, i.e. EurepGap guidelines, about 1,5 % is organic and the remainder are conventionally growing.

<u>Control strategy of apple scab</u>
Weather conditions
The weather conditions are in general very favourable for apple scab. A lot of days with some rain, a few days with heavy rains. Scab is one of the most important diseases on apple in the region. Most sprayings are against this disease. The severity is high. Nectria is other important disease.

Cultural methods and orchard management
Growers have small, open trees. In this way the quality of the fruits is optimal and the leaves also dry faster but this is not the main reason for the tree-form. Growth regulation is used to prevent that the trees start to grow again in the summer /autumn as leaves formed in this period are very susceptible for scab. Measures for improvement of soil activity are used, e.g. consideration for the earthworms and application of urea to improve better decomposition. Irrigation is used by most growers, they have overhead sprinklers and drip irrigation as a regular water supply is very important for fruit quality and size.

Decision support system
The scab warning system Rimpro is generally used as warning system to advice growers. A climatic network is available for growers where they can login to follow the situation in their own region. When scab-problems develops somewhere it is quickly communicated through the advisory system

Monitoring
Systematic monitoring is not made, as the primary goal of the advisors is to prevent scab, not to count it. Level of scab-inoculum is orchard related and handled accordingly.
When there are problems with scab, the situations is analysed and if needed the control strategy adjusted.

Fungicides
Fungicides used are captan, dithianon (Delan), tolylfluanide (Eupareen), difenoconazol (Score), pyrimethanil (Scala) / cyprodinil (Chorus), dodine (Syllit), metiram (Polyram), pyraclostrobin + boscalid (Bellis) and sulphur. Captan and dithianon are the most used products.
Strobilurines (kresoxym-methyl (Stroby) / trifloxystrobin (Flint)) are not used against scab anymore due to resistance risk, but is still used against powdery mildew.
In conventional growing sulphur is used 1-2 times by app. 25% of the growers.
The basic strategy is preventative treatments and after risky situations (high RIM-values) curative treatments are used.
Most important factor for choice of product is efficacy and no/low risk of russeting. For considerations on environmental and human health the growers rely on supervision from governmental institutions. The frequent use of fungicides is not regarded as a major

environmental problem as the most environmental unacceptable fungicides have been forbidden or restricted in use by registration authorities.
Fungicide resistance development is regarded as a major problem. The reduction in number of products with different mode of action is increasing selection pressure and the remaining curative products are threatened by resistance. Future problems are feared if no new products are developed.
The advisory system is not making any monitoring of shift in sensitivity of the scab population to the fungicides. Here the growers and advisors rely on monitoring programmes by the producers.

Sanitation
Measures for sanitation are regarded as a standard practice by most growers.

Resistant cultivars
The main cultivars are scab susceptible (Elstar, Jonagold), only few hectares with scab resistant cultivars are grown in conventional orchards (<1%). Resistant cultivars are treated with scab fungicides 2-3 times per year to reduce selection pressure as break down of *Vf* resistance has been observed. Spraying may also be required due to other diseases like new emerging diseases such as Fly Speck and Black Rot (*Sphaeropsis malorum*).

Knowledge gaps - Perspectives
Perspectives: currently the most important approaches used to control scab are (in ranked order): fungicides, sanitation, resistance, but for the future the ideal approach would be: resistance, sanitation, fungicides, but that is depending on the success of the breeders.

Conclusion
For the moment and the coming years the present strategy is regarded as durable but new fungicides with new mode of action would be welcome. The growers are generally successful with the present strategy of preventative sprayings but frequent sprayings is expensive and require much time but is regarded as necessary to avoid serious scab problems and subsequent economical losses.

4.2.7 Rhone Valley, France

5 Professional organisations (PO) and a grower replied to the questionnaire:
Fruitiers Dauphinois (B. Duculty), CFCR Chanabel (C. Germain), Chambre d'Agriculture du Rhône (C. Gratadour), PARET-COUZE (P. Paret), Chambre d'Agriculture du Vaucluse (V. Ricaud), GR CETA Basse Durance (P. Borioli).

1. General information about the region
The collected information represent 832 growers from two zones: the middle Rhone Valley and the lower Rhone Valley. The average size of the orchards is 10 ha in the first case and 20 ha in the lower part of the valley. The main growing system used is central axis trees grafted on rootstocks Pajam 1, 2, M9, Malus 111, and M 106.

2. Control strategy of apple scab

Weather conditions
The weather conditions for the Middle Rhone Valley are favourable for scab, mainly in May. The average year amount of rain ranges from 600 to 800 mm. The severity of the disease is considered not high, however in some cases can be considered as intermediate.
In the Lower Rhone Valley the weather conditions are not favourable for scab or only during the primary period. Average year amount of rain ranges from 500 to 650 mm. Globally the severity of the disease cannot be considered high. The disease can be severe once each 5 year, due to primary contaminations.

Cultural methods and orchard management
No cultural method is done especially in regard to the prevention of apple scab, but the growers try to avoid too vigorous trees which can be favourable to the disease.
All the orchards are irrigated, with different types of irrigation.

Decision support system
Decision support systems are used in both the middle and lower Rhone Valley. In the middle Rhone Valley the data used for the forecasts are collected using automatic weather stations; the data are provided by the PO or obtained by SRPV. The two Software Clean Arbo or Vintage are used to determine the risks of infection. The information provided to the farmers is: risks of infection (for the 6 PO), rainfall, ascospores maturation and ejection, incubation period (one case). In the Lower Rhone Valley the CIRAME network (warning system) provides data on risks of infection, rainfall, ascospores maturation and ejection. The feedbacks of the farmers on the systems are positive.
Own weather observations of the grower is not frequent, but possible (one example in the replies).

Monitoring
Monitoring of scab in the orchards is done at least once during the primary period (generally towards the end of the period) and in some cases observations are done during the secondary infection period. Rarely, and only for the varieties as Pink Lady which are harvested late in the season, observations are done autumn. The monitoring is used to verify if an important infection period has been covered by fungicides, and to stop the treatments if the primary season is finished and no lesions observed.
In the majority of the replies, the inoculum at the scale of a group of growers or the region is not taken into account. In one case, sanitation if the inoculum is high in the region and adoption of anti-resistance strategy if resistance to a fungicide is present in the region are cited.

Fungicides

The preferred fungicides are the contact fungicides (first dithianon and captan, second mancozeb and dodine). Copper compounds (only at the beginning of the season) and sulphur are rarely used. When a curative effect is required, DMI (not more than 3 per year) and, in some cases at the beginning of the season, anilinopyrimidines are used. The number of treatments per year ranges from 5 to 10. In the majority of the cases: 7 to 8 treatments.
While choosing a fungicide the most importance criteria are the activity and the good adaptation to stage or climatic conditions. The price comes generally after. Considerations about environmental and human health were in all cases rated as less important.
Resistance management is done by alternation of products with different modes of action, limitation of the number of treatments of some families (strobilurines, DMI), use of contact products, mixtures of DMI and strobilurines with contact fungicides.
As obstacles for a better resistance management is the lack of products with different mode of action as been reported from 3 out 6 professional organisations and growers. One organization reports that an additional obstacle is the use of contact products for the production of baby food and the limitation of treatments before the crop.
Concerning reduced efficacy of some fungicides that cannot be explained, in one case lack of efficacy of anilinopyrimidines in 1999 and 2004 is cited. A problem is reported in pear orchards: scab is a problem in some orchards of the Lower Rhone Valley, on cv Williams, and this scab is not controlled by conventional treatments (only DMI has been efficient in 2007).

Fungicide resistance

Resistance to strobilurines has been reported for the Middle Rhone Valley, but so far is not causing important problems. Also in the Lower Rhone Valley resistance to strobilurines has been reported, and seems more frequent in this region; moreover it is suspected that also resistance towards anilinopyrimidine has been developed. So-far only resistance against strobilurines has been experimentally proved in the laboratory.

Sanitation

Treatment with urea and shredding leaf litter are the two sanitation practices used. Up to 70% of the growers apply urea and up to 50% shred leave litter. It is difficult to estimate the success of sanitation as in the Lower Rhone Valley the disease pressure is not high, and in all region these techniques have been applied only recently. Sanitation is used as routine practice by 50% of the farmers and is used by the other 50% of the farmers only in problematic orchards. In the majority of cases, the cultivar susceptibility influences the use of sanitation practices.

Resistant cultivars

Resistant cultivars grown in the Rhone Valley are Ariane, Dalinette, Doriane, Goldrush, Juliet. While choosing the cultivar commercial interest and agronomic characteristics are more important criteria than resistance to scab. The percentage of the acreage of all the resistant cultivars is estimated to 1%. For the susceptible cultivars the percentage of acreage is (lower-middle Rhone Valley): Golden 20 - 35 %, Gala 15 -20, Red delicious 9 -17, Granny 0 -15, Pink Lady 2 -7, Fuji 0-4, Braeburn and Reinette Grise : 0 – 5, Idared 0 – 3.
In the Rhone Valley resistant cultivars are managed indifferent ways: no treatments, 2 to 3 treatments during infection periods or regularly treated when only some rows of the resistant cultivars are planted in an orchard of susceptible cultivars. NO resistance breakdown as been reported in this part of France.

Durability of the strategy

The majority of growers think that the used strategy is durable, and are satisfied.

In 3 cases, problems mentioned for the future are the absence of new fungicides and diminution of fungicides available. Apple scab is not an increasing problem in Middle Rhone Valley, and in Lower Rhone valley the disease represents a problem only 1 year per 5, and can be considered globally as a decreasing problem.
The negative impacts of the strategy are resistance to fungicides and effects of contact products on Thyphlodromus (in only one case). There are very divergent opinions on the most important approach to control the disease.
Only the possible retreat of captan is cited as future problem, and gaps in the knowledge concern pear scab and not apple scab.
The most relevant websites and documentation sources are:

- Warning systems (SRPV or other Bulletins)
- Sites of reviews, firms or IPM sites
- Information available by different experimental stations or organisms (CEHM, CTIFL)
- Technician networks, meetings of "Groupe national tavelure"

4.3 *Elements of the strategy*

4.3.1 Cultural methods and orchard management

Use of cultural methods is not only for the purpose of preventing apple scab but is a part of the integrated orchards management. Various cultural methods are used to ensure harmonic growth of the trees. This includes planting of good quality trees, adaptation of fertilisations to the needs of the trees and proper pruning and, if necessary, irrigation. Good soil activity is regarded as important for mulching of leaves and several advisors mentioned restricted use of copper as a way to protect earthworms.

4.3.2 Decision Support Systems

Different decision support systems (DSS) are used in various ways in all regions. Extension services or advisors use information from weather stations, spore traps, automatic systems like RIMPRO and observations from the field to forecast risk periods and give recommendations for application of fungicides. This is communicated to growers in various ways, traditionally by fax, phone, in written and verbal communication, but new technologies like e-mail, SMS and web pages are used more and more. Growers use this information together with their own weather observations and experience. Few growers have their own DSS system.

4.3.3 Monitoring

Systematic monitoring is made by advisors in some regions and is used to adjust the recommendations, but in other regions adjustments of the strategy are based on running observations by the growers and consultation with the advisors. The most common monitoring done by the growers is the observation of fruit damage during harvest. Sometimes this information is used to plan the strategy for scab control in the following year.

4.3.4 Fungicides

Generally the use of fungicides is based on protective strategies, where applications are made when DSS systems (combined with weather forecasts) predict a risk period. The number of applications varies from 5 per season in areas/years with low risk of apple scab up to 25 in high-risk areas/years. The possibilities for curative treatments are limited in several regions due to resistance problems. Resistance problems have been reported for sterol synthesis inhibitors, anilinopyrimidines and strobilurines. Systematic monitoring of fungicide sensitivity is generally made by the chemical companies and the results are often not known to the growers. Anti fungicide resistance development strategies are based on the use of

preventative fungicides with multi-side action, alternations and tank mixtures of products with different mode of action. When an advisor is consulted in case of lack of efficacy, it is often found that the reason is either incorrect timing or wrong choice of product or a poor application technique rather than development of resistance to a fungicide.
The criteria for choice of fungicide is firstly effectiveness, secondly mode of action. Price is only mentioned as a secondary criterion. It becomes slightly more important if the orchards are large. The (IP) growers do not consider environmental characteristics of the fungicides as this is expected to be considered by the authorities during the registration process.
Several advisors mentioned that availability of few fungicides with different mode of action and lack of new products is a potential risk to resistance management.
Use of natural products is limited to sulphur and copper. Apart from these only lime sulphur is mentioned as being used but only in organic orchards.

4.3.5 Sanitation

Sanitation is commonly used in all regions, especially in cases where high incidence of fruit scab is recorded at harvest. Standard practice is spraying of urea, in some regions lime nitrogen or copper, followed by mulching or removal of the leaf litter.

4.3.6 Resistant cultivars

Resistant cultivars are rarely grown (< 1% of the area), even in organic orchards. The main criteria for the choice of cultivar are commercial interest and agronomic characteristics. The main reason for not choosing a resistant cultivar is lack of cultivars with sufficient market quality. The most grown resistant cultivar is Topaz.
If a resistant cultivar is grown, spraying for control of apple scab is still made up to 8 times per season, both for control of other fungal diseases and to prevent breakdown of the scab resistance. Confirmed breakdown of *Vf* resistance, among the studied regions, is only reported from the Netherlands.

4.3.7 Knowledge gaps

Following points are mentioned as knowledge gaps:

- Importance of conidia spores for primary infections
- Survival period for ascospores which do not germinate during an infection period
- Epidemiology during summer, what are favourable conditions for secondary infections?
- Influence of winter conditions on development and maturation of ascospores
- Impact of hail nets on scab development
- Lack of local validations of DSS and precise interpretation of DSS information

4.4 *Conclusions*

Generally, the strategies are regarded as durable. Much knowledge exists about the process and control of primary infections and is used together with weather stations in various DSS. The information is effectively made available for growers through extension services and modern information systems such as internet and sms.
Apple scab control is a part of a total integrated orchard management, where use of preventative measures is constantly improved. The aim is to reduce the possibilities for establishment of apple scab and prevent epidemics. It is a pity that resistant cultivars are used very little due to lack of sufficient market quality. Maybe it could be promoted or enhanced via crop specific IPM standards. Further development of sanitation practices, such as improving leaf degradation by earthworms is recommended. Little reseach is done on leaf degradation by earthworms in orchards.

Control strategies are based on the use of preventative fungicides, and the number of applications varies very much, due to regional differences in climate conditions for scab development.
Few curative fungicides are available and the number of treatments is kept low to prevent development of fungicide resistance, which is a problem in some regions. The loss of several fungicides without suitable new products is a matter of general concern.
Overall, the control of apple scab is working well but further knowledge about the epidemiology of conidia infections (secondary season), more precise interpretation of DSS information availability of resistant cultivars with improved fruit quality, as well as a more forced sanitation (removal of leaf litter during the winter) may all be ways to further improvement of the strategies for apple scab control and possibly reduce the dependence of fungicides in the strategies.

5 Toolboxes of integrated control methods

5.1 *Toolboxes for codling moth*

The toolboxes for the different regions in Europe contain a variety of different tools for integrated control of codling moth. Some of the tools are still under development and some are continuously further developed. The ones used in practice are:

- Population and Damage Monitoring
- Use of Decision Support Systems
- Orchard Management Practices and Use of Sanitation Practices
- Non-Chemical Control Methods
- Chemical Control Methods
- Pesticide Resistance Management and Resistant Populations

During the inventory, it became clear that knowledge on integrated control methods is well spread throughout Europe. This accounts at least for the regions covered in this study. It might well be that newer European member states have a different situation. It is worthwhile to investigate this situation. Spreading this information through Endure channels would be most valuable in the case the information is not readily available in those countries.

In the southern countries up to three generations of codling moth occur, while in northern European countries often only one generation is completed. Despite this marked difference, there is no substantial difference between countries in the use of different tools of integrated control of codling moth.

Some tools, like biological control, are still under development. Other tools are ready but little used. Bottlenecks for further implementation are most often practical reasons. Investigation and analysis of bottlenecks is important to overcome hindrances.

5.2 *Toolboxes for brown spot of pear*

Brown spot of pear is a new disease and nearly and toolboxes of integrated control methods are still very limited. Most tools are still under development. The ones used in practise are:

- Decision support systems
- Sanitation practices
- Chemical control methods and resistance management
- Resistant cultivars

Since the majority of tools for integrated control of brown spot are still under further development, the exchange of information between countries is mainly through classical scientific channels. A first European workshop on brown spot was held 2005 and the second one was held in October 2008.

Normally diseases in fruit crops are more important in northern European countries than in the south, because of wetter climates promote disease development. Brown spot of pear is an exception. The disease develops more virulent under warm conditions such as in Spain and Italy.

Brown spot of pear mainly occurs in two northern countries Belgium and the Netherlands and in two southern countries Spain and Italy. The southern countries had an advantage in time for development of knowledge and development of integrated control methods, because the disease was first observed in those countries. At the moment there are little differences in toolboxes for integrated control methods between northern and southern countries. Only sanitation is done more frequently in southern countries than in northern.

In general bottlenecks for introduction on tools for integrated control methods are economical and practical. Especially the choice of cultivars is done mainly on economic motivation and crop protection measurement don’t play a role. A bottleneck more specific for brown spot on pear is the lack of knowledge. This causes superfluous fungicide applications as an insurance of fruit growers to avoid damage.

5.3 *Toolboxes for apple scab*

For apple scab there is a long history of integrated control. The toolboxes with integrated control methods are well filled with a wide range of different tools, which are sometimes well established and based on sound scientific research. A number of tools for integrated control are used in practice. These are:

- Cultural methods and orchard management
- Decision support systems
- Chemical control methods and resistance management
- Sanitation practices
- Resistant cultivars

Apple scab is more important in northern Europe than in southern Europe. Non-the-less, toolboxes with integrated methods are very similar. There are some difference is the extent of use of the different tools. For example, sanitation by the use of urea is more often done in northern countries and leaf shredding is done more in southern counties. The reason is that in southern counties, the conditions in autumn are normally dryer than in northern countries. This makes driving in the orchard more easy. Knowledge of apple scab is well and rapidly spread among growers all over Europe. This is mainly done extension services, who sometimes consider this as a substantial part of their tasks.
Like in brown spot of pear, less susceptible cultivars for apple scab exist and some cultivars have the Vf-gene and are resistant. They are hardly used in practice of integrated culture. Only organic fruit growers plant resistant cultivars. Economic motivations are more important than resistance properties when choosing new cultivars.

5.4 *Conclusions*

From the analyses of the collected information the following conclusions are drawn.

- Knowledge on integrated control methods is in generally quickly and well spread in the European countries involved in this study.
- Spreading of knowledge is done by governmental or private organisations often by extension services.
- Information on timing of pesticide applications based on decision support systems is often done with modern communication technologies, like SMS and e-mail.
- Toolboxes contain the same tools for integrated control of the three pests / diseases from this study in all regions covered in this study. Hence, there are no differences between northern or southern regions within Europe in this aspect.
- Even the importance of the different tools is very much similar in northern and southern regions in Europe.
- There are only small differences in the percentage of growers using the different tools for integrated control between European fruit producing regions.
- It is unknown if newer European member states have access to up to date information on tools for integrated control.
- Newer European member states could profit existing knowledge through Endure channels of communication.
- There are clear bottlenecks in adopting newer tools of integrated control. For example the major bottleneck for growing less susceptible of resistant cultivars is that these have less economic value.
- Bottlenecks for implementation of new integrated control measures often have multiple back ground, especially technical and economical reasons.
- Control is much dependent on the use of pesticides, especially in the case of pathogens.

- Decision support systems and monitoring damage should be used as basic tools of an integrated control strategy.
- Major bottleneck, in general, for integrated control is the lack of selective pesticides. For codling moth this is not the case. For many other pests and disease, the non-slective pesticides harm natural enemies and antagonists.
- A bottleneck is that the registration of products and also products which are generally regarded as safe (GRAS) is tedious and costly.
- Area wide and pluriannual strategies for codling moth and other diseases and pests are required for more durable control strategies and tools.

Appendix 1 Questionnaire used to collect information

ENDURE – Pome Fruit Case Study
Survey regarding control of apple scab

Region:

____

Completed by:
Name:

____

Organisation:

____

1. General information about the orchards in the region

Number of growers	
Average size of orchards	
Growing systems (Dwarfing, rootstock etc.)	

2. General information about the environmental conditions

Are the weather conditions favourable for apple scab? *- amount (mm) of rain per year* *- distribution of rain (every few days some rain, rare but heavy rains,...)*	
Is the severity of the disease high in the area?	

3. Cultural methods/orchard management

Are some of the following cultural methods practised particularly with regard to apple scab control? - *Spacing trees adequately and pruning (faster drying of leaves)*	

- *Conservative nitrogen nutrition (less young, susceptible leaves)* - *Strategies to improve soil activity (better decomposition of leave litter)*	
Is irrigation needed? Type of irrigation (e.g. sprinkler, drip irrigation)?	

4. Three main approaches of disease management for apple scab
A. Fungicides

Use of decision support systems *- Which systems are available? (If more than one, which ones do you recommend?)* *- How are they organised?* *- What information do they provide? (flight of spore,..)* *- How many growers are using them?* *- Do you have feedbacks of growers about the systems?*	
Own weather observations of the growers? (temperature, wetness of leaves,…)	
Monitoring of scab in the orchards? (What kind of monitoring is done during the primary and secondary infection, autumn)	
How does the result from the decision support system and the monitoring influence the control strategy?	
How does the inoculums present at the scale of a group of growers or of the region influence the control strategy?	
Which fungicides are used and how often do growers spray them?	
Can you classify the reasons of the choice? *- Price* *- Activity (preventive, curative)* *- Good adaptation to climate or phenological stage* *- Side effects* *- Environmental or human health considerations*	
Are alternative products such as biological product and naturally occurring substances used? (Products	

permitted in organic production) *- If yes, what is the percentage (rough estimation) of treated area, compared to chemically fungicides?*	
Resistance management? *- Which strategies are used to delay/prevent development of resistance?* *- Is fungicide resistance a problem?* *- If so, describe which kind of resistance and how widespread it is* *- Has this observation been experimentally proven (in the laboratory)?* *- Are there any obstacles in resistance management? (lack of products with different mode of action,…)* *-Did you observe reduced efficacy of some fungicides that cannot be related clearly with known resistance problems or other reasons ?*	

B. Sanitation

Control of the leave litter *- If yes, what strategy is used? (mulching, treating with chemicals,..)* *- Percentage of growers using it?* *- Success?*	
Other sanitation practices? *- Which?* *- Percentage of growers using them?*	
Is sanitation used only when scab problems occur in the orchard, or like a routine practice?	
Does the cultivar susceptibility influence the use of sanitation practices?	

C. Resistant cultivars

Which cultivars (susceptible/resistant) are grown? Why?	
How are resistance properties ranked in relations to other characteristics when choice of cultivars is made?	
What percentage of the acreage do the different cultivars cover?	
Resistance management? (mix of cultivars in an orchard)	

Are the scab resistant trees treated with fungicides? How often?	
Has resistance breakdown been observed?	
Do you observe the appearance of new diseases?	

5. Conclusions

Do you think that the current strategy used in your region is durable?	
Are scab problems increasing or decreasing ? Why ?	
Consequences of the strategy *<u>Negative:</u>* *- emergence of secondary pests* *- economical risk (negative influence on yield and/or quality, environment friendly strategies are more expensive, …)* *<u>Positive</u>* *- Encourage of beneficial organisms?*	
Which is the most important approach: fungicides, sanitation, and resistant cultivars? (please rank them)	
In general, are you happy with your strategy? *- Bottlenecks (specific problems for this region influencing the choices of the strategy)* *- Do you see gaps in the knowledge? (which information are you missing?)*	
What are the most relevant websites and what documentation material are used to communicate strategies to the farmers?	