# PURE: WP5 –Milestone MS14

## Descriptions of most important innovative non-chemical methods to control pests in apple and pear orchards






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**Pictures**

Left: Apple scab (Bart Heijne), Pear psylla (Bart Heijne), Fireblight (Georg Bantleon)

Right: Codling moth, Stemph-fruit and Earwig (all Bart Heijne)

## Glossary

Alternative crop protection methods/measures: All plant protection measures without synthetic-chemical pesticides; in this report also called non-chemical measures.

Pest: For convenience in this report pests cover all kind of pests, weeds and diseases that disturb and damage the crop (here apple and pear) in growth, production and quality.

Pesticides: All chemical plant protection products including synthetic chemicals (fungicide, insecticide, herbicide, bactericide) and natural chemicals (copper, sulphur, azadirachtin, mineral oil). The latter are consistent with organic farming.

## Abbrevations

BCA: Biological Control Agent
CAS_nr. = registration number for an active chemical ingredient with CAS Chemical Abstract Service
CIMET:  a model
CIRAME: name of a plant protectionnetwork in the Rhone Valley, France
DSS: Decision Support System
ENDURE: European Network for Durable Exploitation of crop protection strategies
EPPO:European and Mediterranean Plant Protection Organization
HU: region Hungary, whole country
IFP: Integrated Fruit Production
INOKI: a model for
IPM: Integrated Pest Management
IT: region Italy: South Tirol, Trentino, and PO-Valley
LC: region Lake Constance, south Germany
MABSD: EPPO code for apple
NL: region Netherlands, whole Country
PAD: method for determining the potential ascospore dose of apple scab
PESAP: Pests of Europe and control Strategies for Apple and PEAR – name of an ACCESS database
PYUCO: EPPO code for pear
RIMPRO: DSS (prediction model) for apple scab
RV: region, Rhone valley, south –east of France
SOPRA: pest prediction model

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# 1. INTRODUCTION

Nowadays the challenge for pest control is high. On the one hand the pest problem is increasing (e.g. throughclimate change) and on the other hand policy rules are getting stricter with respect to pesticide use and the acceptance of theirecological risks.For instance the agricultural policy demands the implementation of integrated pest management (IPM) in Europe by 2014(Mouron et al. 2010). Although IPM is a key topicinresearch hand well known bygrowers, in practice, pest control is mainly achieved by pesticides (Mouronet al.2010). At present, the amount of pesticide use is still rather high considering human health and "ecotoxicity"(ENDURE- Deliverable DR3.12).Future pest strategiesmust match the demands of lower environmental and health risk for workers and economically sustainable fruit productivity and quality.

The solution is keeping the frequency and dose of chemical pesticide application at a low level by i) precision farming in space and most of all in time using decision support systems (DSS),ii) replacing chemical pesticides by ecological rather harmless pesticides and biological control with natural enemies, iii)reducing the pest pressure with cultural methodsas sanitation and iv) making the crop less susceptible to the pest with cultural methods thatstrengthen their robustness and the choice of the resistant or tolerant cultivars.

A comprehensiveoverview on IPM tools and even more about their use in practice is not yet available. Moreover, further tools are required and the individual tools have to be combined to toolboxes with strategies for optimizing IPM. The objective of this report (M14) is the collation of existing and innovative non-chemical tools for key pests and diseases of pomefruit in 5 European regions.This report gives also a brief overview of the major pests in apple and pear orchards for the 5 regions in the context of their climatic and common cultivation conditions. The report is meant to be used as a guide within the frame of the PURE project (WP5) for the identification of innovative IPM tools and assembling IPM solutions for pest control in pomefruit, i.e. developing for each key pest and region specific toolboxes, consisting of a set of complementary, promising toolsand strategies for pest management. In order to achieve this aim and to ease the data collation a database was developed. In a later step the database will be linked to assessment tools for ecological and economical evaluation of the various defined pest strategies.

# 2. MATERIAL AND METHODS

## 2.1 Regions

Pest control methods and needs differ with the ecological conditions of a certain land use system. In this study on innovative IPM solutions, the main important environmental conditions of European pome fruit orchards are taken into consideration. The investigated pome fruit regions were from the north to the south: The Netherlands (whole country, NL), Lake Constance (LC, Germany), Hungary (whole country, HU), Rhone valley (RV, France) and Italy (IT, South Tirol and Trentino, Po Valley). These are 5 of the major pome fruit production regions in Europe and they represent the main ecological conditions of European apple and pear orchards (ENDURE- Deliverable DR1.8 &1.9). The climatic condition in the southern region (Rhone Valley, North Italy) is much warmer and dryer than in the northern regions (Germany, The Netherlands). Accordingly, the pressure of the various pests varies with the north- south gradient (Buurma 2010).

*The Netherlands - NL*

The production areas of apple and pear are rather similar with resp. 9.500 and 7.000 ha (ENDURE-Deliverable DR1.8 &1.9; Centraal Bureau voor de Statistiek (http://statline.cbs.nl/StatWeb/publication/?VW=T&DM=SLNL&PA=80780NED&D1=180-193,250-263&D2=0,5-16&D3=10-11&HD=111122-0744&HDR=G2,G1&STB=T). The area of pear is gradually increasing. The climate is mild with average winter temperatures of 3 $^{o}$C and mean summer temperatures of 17 $^{o}$C. The mean annual rainfall of 800 mm is well distributed, i.e. there are many wet days with low rainfalls in NL which benefits apple scab and the development of brown spot of pear.

*Lake Constance - LC*

Lake Constance (LC) has with 8.000 ha an apple production in Germany (23% of German orchards) similar to the north German areas, while its pear area covers only 500 ha. Other crops play a minor role in LC. The climate is rather mild. The annual rainfall is well distributed and ranges from 750 mm in the west to 1200 mm in the east of the region. The sandy- clay soil is suitable for apple production. Frequent rains during summer ease the infection with *Venturiainaequalis*. (pathogen for apple scab) and high temperature sums form a good condition for the infection with *Erwiniaamylovora* (pathogen for fireblight), respectively. Moreover, codling moth forms a medium problem.

*Hungary – HU*

Hungary (HU) has a large apple areaof 25.000 ha and the pear area covers 2500 ha. Other crops such as sour cherry and plum play an important role in fruit production. The climate is continental. The annual rainfall is sporadic and ranges from 450 mm and 600 mm in the Eastern region. The soil type is mainly sandy- clay. Frequent rains during springcan support epidemics of apple scab (*Venturia* spp.) and high temperature sums form a good condition for the infection with *Erwiniaamylovora*. Codling moth forms a medium to high problem.*Cacopsylla* is the major pear pest, causing large economic problems every year. Mild early spring and hot summer can promote its gradation in Hungary.

*Rhone Valley - RV*

An area of 14000 ha apple and 3.500 ha pear cover the Rhone Valley (RV, considering the two regions Provence Alpes Côte d'Azur and Rhône Alpes). The climate is characterized as Mediterranean in the lower Rhone Valley and continental in the middle Rhone Valley, i.e. very warm and dry summer and wet periods in spring and autumn. Irrigation is required in most orchards. Orchards are often protected by windbreaks against strong wind like the mistral. The mean rainfall ranges from 600 to 800 mm in the Middle RV (favorable for apple scab) and 500 to 650 mm in the Lower RV (scarce scab problem). There is a high codling moth pressure, while Rosy apple aphid is an increasing problem and fireblight a punctual problem.

*Italy – IT*

The pome fruit area with apple is very large 18000 and 12000 ha in South Tirol and Trentino, respectively. The largest pear area (26290 ha) is located in the Po valley. The mean annual precipitation is 750 mm in South Tirol and 900 mm in Trentino. Here, the rainfall amount dropped up to 600-700mm during the last years, so that the usual high apple scab problem could decrease. In Emilia Romagna (Po Valley), there are two rainy seasons with heavy rainfalls, one in spring (from March to mid-May) and one in autumn (October-November). The summer of this sub-continental climate is hot and dry which requires often irrigation. The climatic conditions of the Po Valley are often favorable for disease development (ENDURE – Deliverable DR 1.8 & DR 1.9), including apple scab and brown spot of pear. Codling moth is the main insect pest.

## 2.2 Data collection

The data collection included major pests and the related major pest control tools in apple and pear orchards. The task was divided per region, each with a responsible expert partner (i.e. authors of this report). For each region first the major pests were identified and then the major tools for control of the identified key pests were listed.The collation was performed with template Excel tables for data entry.The Excel formats were sent per e-mail to the regional experts, who made use of two types of information sources:

1. inventory of pest management in pome fruit by various surveys among farmers and experts: an ENDURE-survey in 2008 among fruit growers (apple and pear) in Germany (Lake Constance) and Italy (Emilia Romana), asurvey in2007among fruit growers (apple and pear) in the Netherlands (whole country) and Italy, and a survey in 2006 -2008 in France (Rhone valley), a Neptun survey in 2004 and 2007 (Roßberg 2006) and an interview of an expert in Italy (Emilia Romana).These information formed the basis for the PURE data collection on pome fruit pest management. Framers surveys are not available for Hungary.
2. regional expert knowledge from scientists and consultant officers for crop protection was an important information source for the five regions. Expert knowledge was the only information source for Hungary .

Subsequently, the collated information was imported in an ACCESS database, here called PESAP (Pests of Europe and control Strategies for Apple and Pear; paragraph 2.3). Finally data queries with PESAP were performedfor the identification of non-chemical tools and common pesticide use.

### 2.2.1 Identification of key pests

In this study, the final criteria for key pests are: 1.) without control the pest causes severe yield losses and 2.) the control of the key pests demands a high amount of chemical pesticides so that the implementation of alternative tools would mean a great contribution to more sustainable and healthy pest management of orchards.The selection of key pests was done as followed:

1. Key pests had been identified during the PURE kick off meeting, based on the findings of ENDURE (ENDURE-survey) and expert knowledge: apple scab (*Venturiainaequalis*) and codling moth (*Cydiapomonella*) for apple orchards and brow spot of pear (*Stemphyliumvesicarium*) and pear psylla (*Cacopsyllapyri*) as major pest in pear orchards.

2. The regional experts of the PURE-WP5 partners listed the“major pests”in the Excel table (as described above). There was no focus on certain pests. The information included a pest ranking by the regional experts (Table1).

### 2.2.2 Collation of control tools

Parallel to the major pests, the related control tools (common and innovative) were gathered in the same Excel table. All type of control measures was considered, the chemical as well as the non-chemical tools. The tools were described by a tool name, the CAS-Nr. (chemical tools) or description (non-chemical tools).Depending on the type, the tool name was either the active ingredient, the EPPO name of the pest predator, the pest resistant cultivar, the cultivation action, etc.. Moreover, the application date/ week and /or dose were surveyed, for the development of pest management strategies. The tools were ranked with respect to their importance of practical use (Table 2).The ranking of tools is given by experts from the point of view of the farmers.The higher the rank, the more important is the tool in terms of frequency, dose and efficiency. Negative ecological side-effects are not considered. For the region LC, the ranking was done by local advisors, while for the other regions scientific experts were in charge. Therefore, those estimated ranks should be taken with care, in particular for the RV region, where the ranks refer to the praxis-based experiments. It should be also mentioned that for certain pests in RV the list of available pesticides and existing resistant or low-susceptible cultivars is large and therefore not complete in this report.Both ranks, for pests and tools, represent the estimation of the regional experts, i.e. scientists and regional consultancies (partners of WP5).

**Table 1.Ranking of pests and diseases by experts of the 5 pome fruit regions.**

| Ranking per region | Definition |
|---|---|
| 0 | seldom, economical not relevant |
| 1 | increasing problem and economically relevant |
| 2 | regular problem with economic damage |
| 3a | pest occurs seldom or regular, existence -threatening |
| 3b | frequent problem with high economic damage |
| -1 | unknown |

**Table 2. Ranking of pest control tools by experts of the 5 pome fruit regions.**

| Ranking per region | Definition |
|---|---|
| 0 | no application/ use |
| 1 | very few application |
| 2 | few application |
| 3 | medium frequent application |
| 4 | frequent application |
| 5 | very frequent application |
| -1 | unknown, how much the tool is used |

## 2.3 Established database

All collected information was brought together in a database (Access), called PESAP (Pests of Europe and control Strategies for Apple and Pear). The database covers information of the data sources and regions, the pests and diseases, the various single control tools and their description. The PESAP structure is presented in Fig. 1. PESAP consists of 10 tables which are linked for data selection, queries and further analysis. The main tables are the ones with the pests and the related control tools. We distinguished between chemical (CC) and non-chemical pest control measures. The non-chemical measures were further differentiated into bio-control (BC), cultivation and mechanical actions (CM), use of crop cultivars that are pest resistant and/or tolerant (PR) and decision support systems (DSS). CC comprises all pesticides that have a CAS number including synthetic chemicals (fungicides, insecticides, herbicides, bactericides) and natural chemicals (copper, sulphur, azadirachtin, mineral oil). The latter are consistent with organic farming. CM covers cultivation actions that protect the fruit trees directly or indirectly against pests, like sanitation or fertilization.

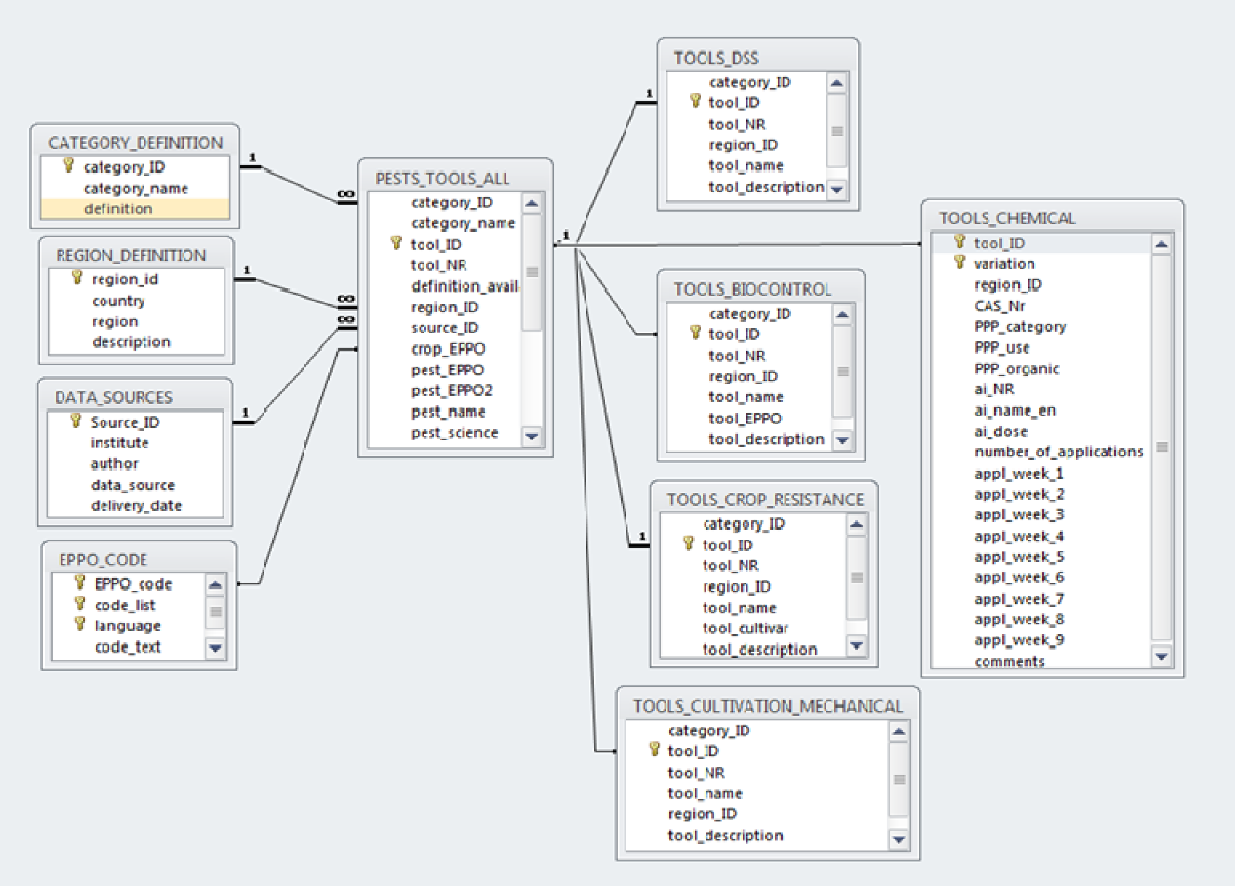


**Figure 1.The PESAP database structure and components (tables).**

Queries with PESAP, taking under consideration the tool rank, revealed for each crop, pest and region i) the tools that are commonly used andii) innovative non-chemical tools with a potential for future pest management. In a next step, the collated chemical and non-chemical tools will be used to build pest control strategies. The PESAP database will ease the strategy development and additional data collation. For the strategies we need further information on the precise treatment application with respect to timing, frequency and quantities of active ingredients application and/ or cultural activities. The database is still in development and, therefore, available for WP5 partnersonly. The tool will be further developed, made user friendly and then put on the PURE-website for easy access to all PURE partners.

# 3. RESULTSand DISCUSSION

## 3.1 Overview of the regional pest problems and pest control methods

In all investigated regions,the preselectedkey pests, i.e.apple scab,codling moth and pear psylla, occur rather regular with an infection level depending on local climate and weather conditions.Whereas brown spot of pear plays neither a role in Germany (due to the small production area) nor in Hungary, but is important in the other regions. Each of these pestsforms a crucial problem and got a high pest rank (Table 1, Table3.1).The data collected during PURE revealed that further pestsplay a role, since they obtained also a high rank. The list of key pests mentioned under point 1 has been extended accordingly (Table 3.1). Several of these pestsare "dormant"that can,given the optimum weather, developrapidly to a serious yield risk. Fireblight is an example thatplays a role in LC.Other pests may benefit from the global weather warming and move from southtowards north Europe.Theextended list of keypests inpome fruit, presented in Table 3.1, includes the English, scientific and EPPO name. The EPPO code of the pest is used in the graphical presentation of the results to ease readability.

**Table 3.1.Major pests in the European regions The Netherlands (NL), Lake Constance (LC), Hungary (HU), Rhone Valley (RV) and Southern Italy (IT) occurring in apple (MABSD) and pear (PYUCO).For each crop and region, the pest importance is indicated by a rank number.* varies regionally**

| **Pest name** | | | **Pest crop** | **Pest occurrence: pest-rank** | | | | |
|---|---|---|---|---|---|---|---|---|
| **Scientific** | **English** | **EPPO** | **Crop** | **NL** | **LC** | **HU** | **RV** | **IT** |
| *Venturia inaequalis* | apple scab | VENTIN | MABSD | 3b | 3b | 3b | 3b* | 3b* |
| *Cydia pomonella* | codling moth | CARPPO | MABSD,PYUCO | 2 | 2 | 3b | 3b | 3b |
| *Erwinia amylovora* | fireblight | ERWIAM | MABSD, PYUCO | 3a | 3a | 3a | 3a | 3a |
| *Dysaphis plantaginea* | rosy apple aphid | DYSAPL | MABSD | 3b | 3b | 3a | 2 | 2 |
| *Podosphaera leucotricha* | powdery mildew of apple | PODOLE | MABSD | 2 | 1 | 1 | 1 | 2 |
| *Quadraspidiotuspern iciosus* | San José scale | QUADPE | MABSD | 2 | 2 | 1 | 0 | 1 |
| | | | | | | | | |
| | storage diseases | PEZIAL, NECTGA | MABSD, PYUCO | 1-3b | 1-3b | 1-3b | 1-3b | 1-3b |
| | | | | | | | | |
| *Stemphyliumvesicari um* | brow spot of pear | PLEOAL | PYUCO | 2 | 0 | 0 | 1 | 3b |
| *Cacopsyllapyri, C. pyrisuga* | pearpsylla, pearsucker | PSYLPI, PSYLPY | PYUCO | 3b | | | 3b | |
| | | | | | 3b | 3b | | 2 |
| *Dysaphispyri* | pearbedstraw | DYSAPI | PYUCO | 2 | 2 | 1b | 2 | 2 |
| *Venturiapirina* | pear scab | VENTIN | PYUCO | 2 | 2 | 2 | 1 | 3a |

Storage diseases and post-harvest diseases are used as a one group, comprising PEZIAL: *Gloeosporium album* (NL, LC, RV), *Botrytis cinerea* (NL) and NECTGA *Nectriagalligena* (NL,IT).

Moreover, *Venturiainaequalis*occurs also as a storage disease in all 5 regions. Weed is a common problem in all regions, but is not regarded in this report. Rodents form a ratherhuge problem in LC(mice) and RV, HU (in particular voles) nevertheless they are not regarded in this report.

Without pest management the pestsin Table 3.1 would cause high yield and economic output losses. In IP,pests are mainly counteracted by means of chemical pesticides. This report includes major chemical tools in order to put the meaning of alternative tools in the right context of pest management.In general, the PURE datareveal low adoption of alternative tools like “granulosisvirus, mating disruption and sanitation” as was already found during ENDURE(RA2.5)(Table 3.2).The control methods used in the Netherlands, Hungary and the region Lake Constance are very similar. Contrary, the growers from the Rhone valley and even more from Italy have their own, different tools. It is striking that the Italian growers give ample attention to alternative methods, although chemical tools are still frequently used. In Table 3.2 the use of natural pesticides (allowed in organic farms) are presented for each region.Over the entire growing period, the growers are consulted by official and/ or private experts in particular with respect to pest control.

*The Netherlands*

The Dutch orchards are intensive fruit production systems and most of them follow the IPM (95 %), but only few (1.5 %) the organic guidelines. For codling moth conventional control strategies are used (ENDURE-Deliverable DR1.8 & DR1.9). From the major pest list apple scab is the most dominant pest requiring a lot of spraying, some DSS and a low/unknown level of cultural actions (Table 3.3). For NL the NECTGA is added to the pest lists. Codling moth and scab have rank 3b.Growers attack this pest with insecticide and the combination of DSS, mating disruption and most of all with granulosisvirus (Table 3.4). The pear growers have to deal with brown spot of pear, pear psyllaand rust mites. While the latter two pests are counteracted with natural enemies (Table3.9), brown spot is solely treated with fungicides (Table 3.8).

*Lake Constance*

The orchards are characterized by an intense production and IP level; about 90% are labeled with IP. The remaining 10% fruit producers follow organic strategies, and this percentage is increasing (pers. comm. Mayr 2011, KOB). About 30 % of the orchards are covered with hail nets. The major pests are apple scab, fire blight and to a lesser extent codling moth. Apple scab is treated like in NL, often in combination with a pesticide against powdery mildew. According to local expertswoolly apple aphid and post-harvest diseases should be considered too. The pest San Jose scale, to treat with mineral oil, is gaining importance. On the first glance the chemical tools (CC) are still the most used ones, followed bydecision support and cultivation & mechanical tools (CM). DSS support is next to scab also a crucial tool against codling moth and fireblight(Table 3.3b, 3.4b and 3.5b).In Germany the regulations for pesticides are strict and many pesticides have been banned, because of their “ecotoxicity”, while they are still in use in the other regions, e.g. mancozeb against scab.There is a high alternation of pesticides to avoid pesticide resistance. With the exception of scab the use of resistant cultivars is raredue to the lack of such cultivars and/ or market reason (consumer preferences).

**Table 3.2.Tools, that are allowed in organicfarms andused in a) appleand b) pear against major pests, here indicate by the pest EPPO code.**

| Tool nr. | Tool name | EPPO pest ranked for the tool and given per region | | | | | |
|---|---|---|---|---|---|---|---|
| | | NL | LC | HU | RV | IT | |
| 1 | apple granulosvirus | CARPPO | CARPPO | CARPPO | CARPPO | CARPPO | |
| 2 | granulosvirus | | CAPURE | CAPURE | CARPPO | CARPPO | |
| 3 | codlemone | | | | CARPPO | | |
| 4 | pheromone | CACORO | CARPPO | | CARPPO | | |
| 5 | pheromone traps | | CARPPO | | CARPPO | CARPPO | |
| | | | | | | ARGTPU | |
| 6 | azadirachtin | DYSAPL | DYSAPL | | | DYSAPL | |
| | | CHEIBR | | CHEIBR | | | |
| 7 | bacillus thuringiensis | CHEIBR | CHEIBR | | ZEUZPY | ARGTPU | |
| | | | | | CAPURE | PANDRI | |
| | | | | | LASPMO | | |
| 8 | bacillus subtilus | | | | ERWIAM | ERWIAM | |
| 9 | nemasys | | | | CARPPO | | |
| 10 | kaolin | | | | DYSAPL | | |
| | | | | | CARPPO | | |
| 11 | copper | | VENTIN | | VENTIN | VENTIN | |
| | | | VALSCE | | | NECTGA | |
| | | | ERWIAM | | | ERWIAM | |
| 12 | sulphur | | VENTIN | VENTIN | VENTIN | VENTIN | |
| | | PODOLE | PODOLE | PODOLE | PODOLE | NECTGA | |
| | | VASAD | VASAD | VASAD | | | |
| 13 | oil | METTUL | METTUL | METTUL | METTUL | | |
| | | QUADPE | QUADPE | QUADPE | DYSAPL | | |
| | | LYGUPA | | | APXXSP | | |
| | | LEPSUL | | | | | |
| 14 | aureobasidium pullulans | | ERWIAM | | | | |
| | | | VENTIN | | | | |
| 15 | mycosin | | ERWIAM | | | | |
| Tool rank: | | -1 | 1 | 2 | 3 | 4 | 5 |

| Tool nr. | Tool name | EPPO pest ranked for the tool and given per region | | | | | |
|---|---|---|---|---|---|---|---|
| | | NL | LC | HU | RV | IT | |
| 1 | granulosvirus | CARPPO | CAPURE | CAPURE | CARPPO | CARPPO | |
| 2 | apple granulosvirus | | | CARPPO | | | |
| 3 | bacillus thuringiensis | | | | CAPURE | ARGTPU | |
| | | | | | LASPMO | PANDRI | |
| 4 | bacillus subtilus | | | | | ERWIAM | |
| 5 | kaolin | PSYLPI | PSYLPI | | PSYLPI | | |
| | | | | | DYSAPI | | |
| 6 | copper | | VENTIN | | VENTIN | VALSCE | |
| | | | ERWIAM | | | ERWIAM | |
| | | | NECTGA | | | NECTGA | |
| | | | | | | PSDMSX | |
| | | | | | | VENTIN | |
| | | | | | PLEOAL | PLEOAL | |
| 7 | sulphur | VENTIN | VENTIN | VENTIN | VENTIN | | |
| | | EPITPI | EPITPI | EPITPI | PODOLE | | |
| | | ERPHPI | ERPHPI | | | | |
| | | PODOLE | PODOLE | | | | |
| 8 | oil | PSYLPI | | | PSYLPI | PSYLPI | |
| | | DYSAPI | | | DYSAPI | QUADPE | |
| | | LEPSUL | | | | EPITPI | |
| | | LYGUPA | | | | | |
| Tool rank: | | -1 | 1 | 2 | 3 | 4 | 5 |

with ARGTPU = Argyrotaeniapulchella, CAPURE = Summer fruit tortix moth, CACORO = European leafroller, CARPPO = codling moth,CHEIBR = small winter moth, DYSAPI= pear bedstraw aphid, DYSAPL= rosy apple aphid, EPITPI = pear rust mite, ERPHPI = pear bud mite, ERWIAM = fire blight, LASPMO = oriental fruit moth, LEPSUL = mussel scale, LYGUPA = common green capsid bug, METTUL= European red mite, NECTGA = eye rot of apple, PANDRI = Pandemisspp., PLEOAL = brown spotof pear, PODOLE = powdery mildew, PSDMSX = Pseudomonas syringae, PSYLPI = pear psylla, QUADPE = San José scale, VALSCE = canker,VASAD = apple bud mite, VENTIN = apple/pear scab, ZEUTPY = leopard moth.

*Hungary*

The orchards are characterized by partly extensive and partly intense production and IP level; about 60% are labeled with IP. The remaining 37% fruit producers follow conventional and 3% organic strategies. The major pests are apple scab, fire blight and codling moth. Apple scab is treated in combination with a pesticide against powdery mildew. According to local experts woolly apple aphid and post-harvest diseases should be considered too. The pest San Jose scale, to treat with mineral oil, is gaining importance. Chemical tools (CC) are the most used ones, followed bycultivation & mechanical tools (CM). There is a high alternation of pesticides to avoid pesticide resistance. With the exception of scab the use of resistant cultivars is raredue to the lack of such cultivars and/or market reason (consumer preferences).Pear: the main pest is codling moth. Pear bedstraw aphid and/or pear psyllid (*Cacopsylla pyri*) are other important pests. Pear rust mite can also develop under low insecticide management. Scab can severely affect the orchard, depending on the cultivar.

*Rhone Valley*

The Rhone Valley is distinguished in Middle RV and Lower RV. All Rhone Valley is dominated by codling moth problem even though Lower RV is more affected (3 annual flights). The wetter Middle RV has more scab contaminations and problems. Storage rot (*Alternaria alternate*) is mainly a problem for late harvesting cultivars when autumn is rainy. The rosy apple aphid is one important problem in organic apple orchards (azadirachtin is not registered in France). The woolly apple aphid can be locally a problem, and mealybugs (*Pseudoccocusviburnii*) are developing. Their importance is according to cultivars and harvest date. Generally there is high tendency for the use of alternative methods. Many new tools under development such as exclosure netting are also used by some growers (initially organic farmers).

As in Hungary, the main pest for pear is codling moth even though early harvesting cultivars are less affected. Pear bedstraw aphid and/or pear psyllid (*Cacopsyllapyri*) are other important pests. Pear rust mite can also develop under low insecticide management. Last, *Agrilussinuatus* (a buprestid wood-borer) is developing in South-Eastern France, mainly in organic and low-input orchards. Brown spot of pear often requires fungicide applications and scab can severely –but very locally- affect the orchard, depending on the cultivar.

*Italy*

In Italy, similar to Germany, the pest management follows for 90% IP and 5-6 orchards are organic farms (ENDURE-Deliverable DR3.14). Also in Italy the number of organic fruit producers is increasing. About 20 % of the orchards are covered with hail nets. The major apple pests are codling moth and fireblight, whereas apple scab plays only a role around Trento in very wet years. Storage rot is regarded as a crucial risk for yield and quality losses. In the future woolly apple aphid, *Cacopsyllamelan* (PSYLME) and PHYMA could become problematic and should gain more attention. The major pear pest is brown spot of pear. It is striking that Italy applies additional chemical tools (different active ingredients) and relative much non-chemical tools which in contrast to the other countries are much more implemented into praxis.

## 3.2Control methods per pest in apple orchards

The control tools forapple scab, codling moth, fireblight, rosy apple aphid, powdery mildew of apple and San Jose scale are described for the 5 regions, i.e. NL, LC, HU, RV, IT.

### *Apple scab – VENTIN (Venturiainaequalis)*

Apple scab is a problem in all 5 regions(with high pest rank, i.e. 3b), but most severe in the cooler and wetter northern regions(NL; LC) in particular in NL with many rainy days (Buurma 2010, Scheer 2011). Correspondingly, the pest control efforts are very intense in the apple region NL, but the number of tools in practice in the other regions is also important (Table 3.3a). Our data show21 different fungicidesincluding two active ingredients that are allowed in organic farming (copperin some countries and sulphur).The alternative non-chemical methods comprise DSS, PR and CM.

**Table 3.3a.Use offungicides against apple scab in the NL, LC, HU, RV and IT region.Figures show the rank per region. * indicate tools allowed in organic farming. A blank field means no application, i.e. =0.**

| Tool nr. | Tool name | Apple regions | | | | |
|---|---|---|---|---|---|---|
| | | NL | LC | HU | RV | IT |
| 1 | captan | 5 | 5 | 5 | 4 | 3 |
| 2 | dithianon | 4 | 5 | 5 | 4 | 5 |
| 3 | mancozeb | 1 | | 4 | 4 | 3 |
| 4 | myclobutanil | 4 | | 4 | | 1 |
| 5 | difenoconazole | 3 | 1 | | 4 | 5 |
| 6 | kresoxim_methyl | 2 | 1 | 3 | -1 | |
| 7 | bupirimate | | | | 4 | |
| 8 | dodin | 1 | 2 | | 4 | |
| 9 | cyprodinil | 1 | 1 | | 4 | 2 |
| 10 | boscalid + pyraclostrobin | | | | | 5 |
| 11 | cyproconazole | | | | | 5 |
| 12 | fenbuconazole | | | | | 3 |
| 13 | penconazole | | | | -1 | 3 |
| 14 | tetraconazole | | | | | 3 |
| 15 | ziram | | | | | 2 |
| 16 | pyrimethanil | 2 | 1 | | -1 | 2 |
| 17 | trifloxystrobin | 2 | 1 | | | 2 |
| 18 | trifloxystrobin + captan | | 2 | | | |
| 19 | metiram | 1 | | | | 2 |
| 20 | sulphur* | | 3 | -1 | -1 | 5 |
| 21 | copper* | | 1 | | 3 | 5 |

*Decision Support System – DSS*

DSS plays a role in all regions, but only in Italy this tool category is of high importance. Here the advisors transfer the results of DSS to the farmers (Table 3.3b). In the Netherlands, Lake Constance and Hungary DSS is based on the prediction model “Schorf” (by formaet, LC) or RIMPRO using data from local weather stations and sometimes verified with additional spore traps. The decision support is mainly based on the combination of weather data and forecasts, spore traps data, RIMPRO or “Schorf” model as well as monitoring on shoots and leaves to allow the prediction of infection periods and optimum control. The prediction work is performed by extensions officer who communicate the results immediately to growers through various media, e.g. phone, fax, email, personal contacts. Some apple growers make additional weather observations and follow weather predictions to adapt the information from the extension officers to their local situation (ENDURE-Deliverable DR1.8 & DR1.9). In the Rhone valley, the professional extension officers use the CIMET-model and provide through a network (CIRAME) rather detailed information to their farmers, i.e. risk of infection, rainfall, ascospore maturation and ejection (ENDURE-Deliverable DR1.8 & DR1.9). This information is subsequently used by the growers for their pest management.

*Cultivation and Mechanical Control – CM*

In the northern region the cultivation practices play a minor role in scab protection. Nevertheless it is known that the removal of autumn leaves and appropriate helps to reduce inoculum in the orchard. The effect can be even enhanced by combining these sanitation actions with BCA-application (Holb & Heijne 2002), but this is seldom used in practice. In Italy, a minimum input of pesticide is a strategy to increase the earthworm population, which in turn will decrease the ascospore potential. Nevertheless,the number of different pesticide in use in high in the region of IT.

**Table 3.3b.The importance of non-chemical toolsagainst apple scab in the NL, LC, HU, RV and IT region. Figures show the rank per region. For RV not all PR cultivars are listed here.A blank field means no application, i.e. = 0.**

| | | | Apple regions | | | | |
|---|---|---|---|---|---|---|---|
| **Category** | **Tool nr.** | **Tool name** | **NL** | **LC** | **HU** | **RV** | **IT** |
| DSS | 1 | decision support system | | | | | 5 |
| DSS | 2 | RIMPRO model | 1 | 1 | 1 | | |
| DSS | 3 | CIMET model | | | | 1 | |
| DSS | 4 | "Schorf" model | | 5 | | | |
| | | | | | | | |
| CM | 5 | litter removal or ploughing | | | 3 | 3 | |
| CM | 6 | litter removal and mulching | 1 | 1 | | | |
| CM | 7 | Restricted pesticide use | | | | | 3 |
| | | | | | | | |
| CM | 8 | calcium cyanamide | 1 | 1 | | | |
| CM | 9 | potassium bicarbonate | 1 | 1 | | | |
| | | | | | | | |
| PR | 10 | cultivar Prima | | | | | 3 |
| PR | 11 | cultivar Priscilla | | | | | 3 |
| PR | 12 | cultivar Golden orange | | | | 2 | 3 |
| PR | 13 | cultivar GoldRush | | 1 | | 2 | 3 |
| PR | 14 | cultivar Group Gala | | | | | 3 |
| PR | 15 | cultivar Fuji | | 2 | | | 3 |
| PR | 16 | cultivar Florina | | | | | 3 |
| PR | 17 | cultivar Topaz | 2 | 2 | | 2 | 3 |
| PR | 18 | cultivar Dalinette | | | | 2 | |
| PR | 19 | cultivar Ariane (single genes) | | | | 2 | |
| PR | 20 | cultivar Florina (single gene) | | | | 2 | |
| PR | 21 | cultivar Santana (single gene) | 2 | | | | |
| PR | 21 | tolerant cultivars | | | | | -1 |

*Resistant cultivars – PR*

Generally growers choose the cultivars for market quality, rather than for their pest resistance (Mayr, pers. comm. 2011). According to Mayr, it is hard to combine these two characteristics, sometimes due to the consumer's inflexibility to change their preferable taste. In IT, a surprisingly high number of different resistant cultivars are grown compared to the other regions. It must be mentioned that for RV not all resistant cultivars are given in Table 3.3b. Contrary to RV, where many resistant cultivars are available, in LC there is a lack of cultivars that are both resistant and of good market quality. Topaz is the most known cultivar. Usually, the resistant cultivars are treated with scab fungicides several times (between 1 – 5 times with a mean of 2-3 times, depending on the cultivar) to avoid their resistance breakdown, however, in RV some cultivars are not treated. Due to the scab favorable climate, the risk of resistance breakdown in NL and LC region is much higher than in RV and IT (ENDURE-Deliverable DR1.8 & DR1.9). That might explain the rather low number of resistant cultivars in these regions.

### *Codling moth – CARPPO (Cydiapomonella)*

This pest is of major importance (rank 3b) in the warm,Southern regions HU, RV and IT, while in NL and LC codling moth is less severe (rank 2) (Table 3.1).From literature it is known that IPM strategies for the control of codling moth includemating disruption, granulosisvirus, sanitation, DSS, some other techniques and insecticides.

*Chemical tools - CC*

Table 3.4a reveals the highly used insecticides (rank 4 to 5), which thereare apple granulosisvirus (RV, NL, LC), methoxyfenozide (HU, NL), indoxacarb (HU, RV), emamectina-benzoato (IT), diflubenzuron (IT, RV), phosmet (IT), chlorantraniliprole (LC)and mating disruption in LC and RV.

**Table 3.4a. Use of pesticides and other toolsagainst codling moth in the NL, LC, HU, RV and IT region. Figures show the rank per region.* indicate tools allowed in organic farming.A blank field means no application, i.e. = 0.**

| Tool nr. | Tool name | Apple regions | | | | |
|---|---|---|---|---|---|---|
| | | NL | LC | HU | RV | IT |
| 1 | diflubenzuron | | | | -1 | 5 |
| 2 | emamectina-benzoato | | | | | 5 |
| 3 | phosmet | | | | 2 | 5 |
| 4 | indoxacarb | 1 | 2 | 4 | | 2 |
| 5 | methoxyfenozide | 1 | 2 | 4 | | 3 |
| 6 | fenoxycarb | 2 | 2 | 3 | 2 | |
| 7 | thiacloprid | 1 | 1 | 3 | 2 | 2 |
| 8 | chlorantraniliprole | | 4 | | | 2 |
| 9 | chlorpyrifos_ethyl | | | | 2 | 5 |
| 10 | deltamethrin | | | | 2 | |
| 11 | spinosad | | | | 2 | 5 |
| 12 | tebufenozide | 1 | 1 | -1 | 2 | 2 |
| 13 | teflubenzuron | | | | 2 | |
| 14 | flonicamid | | | | 2 | |
| 15 | flufenoxuron | | | | | 2 |
| 16 | apple granulosvirus* | 5 | 5 | 2 | 4 | 5 |
| 16 | mating disruption* | 2 | 4 | 2 | 4 | |
| 17 | codlemone* | | | | 3 | |
| 18 | nemasys* | | | | 2 | |
| 19 | kaolin * | | | | 3 | |

Chemical tools and their timing of application is in all studied regions of uppermost importance. Although there is evidence that insecticide requirements exist only when population around traps is important. In IT, granulosvirus and mating disruption with the codlemone pheromone are not widespread in the Po Valley; according to ENDURE-Deliverable DR1.8 & DR1.9, mating disruption is used by 75 % and 30 % of the growers in South Tirol and Trentino, respectively. Nemasys are nematodes that are applied at the end of the season in France.

*Decision Support System - DSS*

DSS is a key tool of consultancy officers in all investigated regions most of all in LC and IT (Table 3.4b). Contrary, the growers rarely make use of DSS themselves, although a growing group of growers in NL use RIMPRO-Cydia based on their own weather station. Decision support models do exist and are in further development, they are highly used in Italy and Germany (rank 5) but not in practice (at least not known) in the other 3 regions. In Italy and Germany, the prediction is based on phenology (adult emergence, oviposition and larval emergence) and temperature sum (ENDURE-Deliverable DR1.8 & DR1.). A new prediction model for the second generation is still in development in HU. So far the RIMPROCydia (NL), SOPRA (LC) and INOKI (RV) model are valued for their predictions.

**Table 3.4b. The importance of non-chemical tools against codling moth in the NL, LC, HU, RV and IT region. Figures show the rank per region.A blank field means no application, i.e. = 0.**

| Category | Tool nr. | Tool name | Apple regions | | | | |
|---|---|---|---|---|---|---|---|
| | | | NL | LC | HU | RV | IT |
| DSS | 1 | new prediction model | 1- | | | | |
| DSS | 2 | decision support system | | | | | 5 |
| DSS | 3 | INOKI prediction model | | | | -1 | |
| DSS | 4 | SOPRA | | 3 | | | |
| DSS | | | | | | | |
| CM | 4 | fruit removal and box | | 1 | | 4 | |
| CM | 5 | exclosure netting | | | | 2 | |
| | | | | | | | |
| BC | 6 | pheromone traps | | | | 4 | 5 |
| BC | 7 | EPN (Nematodes) | | 1 | | 2 | |

*Cultivation and Mechanical Control - CM*

Generally, growers pay not much attention to CM as a control method. Only two cultivation and mechanical tools are identified beside one biocontrol method (Table 3.4b). Our data show, that sanitation through fruit removal and wood pallox cleaning (or storage outside the orchard, in plastic pallox) is a common tool and used a lot in France (rank 3-4). Exclusion netting of the pest is an innovative tool under development (www.alt-carpo.com). Either each row is wrapped into a net (4x4 mesh) or the conventional hail nets have to be adapted: the complete orchard is covered with the hail net (or best with a net of smaller 4x4 mesh) and sides are closed by a 4x4 mesh net, having one opening door to enter this multi-row exclusion system. The nets need to be closed from end bloom until harvest. This method is already in practice in RV and seems to be promising provided there is no detrimental effect of the nets on the control of other pests or fruit yield (recent program in progress, Sauphanor and Severac, 2011).

*Biological control - BC*

Pheromone traps (tripping 2 adults per trap of 1% hole in 100 fruits) are widely used in Italy and frequently in RV. This method is used a lot (Table 3.4b) by extension officers and some growers for monitoring of the population development (ENDURE-Deliverable DR1.8 & DR1). According tothe ENDURE investigationsthis method was performed in LC and NL by the consulting institutions. The monitoring of the codling moth population with pheromone traps is not working well; the method should be improved, e.g. with pear ester traps (Knight et al 2006). In Italy and France, Biocontrol (BC) finds some interest, most of all through Entomopathogenic nematodes (EPN): an autumn applications on trunks and soil works against diapausing larvae.

### *Fireblight – ERWIAM(Erwiniaamylovora)*

With the exception of RV (rank 2), fireblight is seen as a pest that occurs seldom, but once an infection took place the damage can threaten the growers existence (rank 3a). The reason is that the infected trees often die or have to be removed. In the region LC, where fireblight is a risk factor since the 90ties, the extension officerspay ample attention to this bacterial disease.Next to monitoring, research is ongoing for resistant species, alternatives to the antibiotic streptomycine, mechanical and biological control methods (Müller et al. 2009, Gernold et al. 2009, Wensing et al 2009, Scheer 2012).

*Chemical tools – CC*

Alternative to chemical tools are highly requested. Firstly, there are only few chemical tools available (Table 3.5a).Secondly, the available pesticides are either not sufficient effective (e.g. prohexadion, copper, *Bacillissubtilis*) or very problematic in terms of ecological andhealth risks (streptomycine sulfate)(Bantleon & Scheer 2011).Streptomycine sulfate is forbidden in France and NL. In Italy, the control seems to rely completely on the tools copper and *Bacillus subtilis* (Table 3.5a and 3.5b).

**Table 3.5a.Use of pesticides against fireblight in the NL, LC, HU, RV and IT region. Figures show the rank per region. * indicate tools allowed in organic farming. A blank field means no application, i.e. = 0.**

| Tool nr. | Tool name | Apple regions | | | | |
|---|---|---|---|---|---|---|
| | | NL | LC | HU | RV | IT |
| 1 | Prohexadion | 3 | 1 | 2 | | |
| 2 | streptomycine sulfate | | 3 | | | |
| 3 | fosetylaluminium | | | | -1 | |
| 4 | copper* | | 1 | | | 4 |
| 5 | *Bacillus subtilis** | | | | -1 | 4 |
| 6 | mycosin* | | 1 | | | |
| 6 | *Aureobasidiumpullulans** | | 1 | | | |

**Table 3.5b. The importance of non-chemical tools against fireblight in the NL, LC, HU, RV and IT region. Figures show the rank per region.A blank field means no application, i.e. = 0.**

| Category | Tool nr. | Tool name | Apple regions | | | | |
|---|---|---|---|---|---|---|---|
| | | | NL | LC | HU | RV | IT |
| DSS | 1 | Mary_blight prediction model | 1 | 5 | | | |
| | | | | | | | |
| CM | 2 | clean pruning | 1 | 1 | 2 | -1 | 5 |
| CM | 3 | tree_removal | 1 | 1 | | -1 | |
| CM | 4 | flower_removal | | 1 | | | |
| CM | 5 | restricted cultivation action | 1 | | | -1 | |
| CM | 6 | low N fertilisation | 1 | 1 | | | |
| CM | 7 | monitoring | | 5 | | -1 | |
| | | | | | | | |
| PR | 8 | cultivar Heimhofer | | -1 | | | |
| PR | 11 | Geneva-type | | -1 | | | |

*Non-chemical tools*

Overall, the growers' effort in preventive sanitation is low (Table 3.5b). However, careful monitoring by consultancy and to an unknown degree by farmers (Table 3.5b) should identify possible infections in an early stage. Additionally, consultancy organizations use models to estimate the infection periods and optimum dates for treatment, based on weather and tree phenology data. In case of infection, clean pruning, flower removal and in the worst case complete tree removal have quickly to take place.Infected material has to be removed by pruning deep into the healthy tree parts. Naturally the pruned material has to be removed and cutting tools have to be disinfected. In infested orchards pruning must be performed with care to avoid further contamination. For the same reasonsanitation and other cultivation work should not be carried out in wet plots which might be infected. Our data collation gives no information to which extent fruit growers do the sanitation job, but according to experts of the LC region the work is performed properly in LC.

As for scab and many other pests and diseases, the potential of infectionsand the spread can be reduced by all means that strengthen the tree health and avoids vigorous growth. In this context, the restriction of N-fertilization is one management element. Another one is the stepwise replacement of the commonly rather susceptible trees by more resistant ones. Old cultivarsasHeimenhofer, Danziger Kantapfel, Maunzenapfeland Rheinische Bohnpafelarerecommended (INTERREG IV Projekt: Bekämpfung von Feuerbrand im Bodenseeraum). Moreover, middle sizes and dense tree crowns ease monitoring.

### *Rosy apple aphid – DYSAPL(Dysaphis plantaginea)*

The economical meaning of the rosy apple aphid varies withinthe European regions. While it is of no or few importance in RV and IT (rank 2), respectively, it is high in HU (rank 3a), NL and LC (rank 3b). At present, the pest is managed solely with chemical tools. The insecticideazadirachtin is allowed in organic farming, except in France where it is not registered. Control strategies that consider the threshold values should be developed as a basis for future IMP strategies.

**Table 3.6.Use of insecticides against rosy apple aphid in the NL, LC, HU, RV and IT region. Figures show the rank per region.* indicate tools allowed in organic farming.A blank field means no application, i.e. = 0.**

| | | Apple regions | | | | |
|---|---|---|---|---|---|---|
| **Tool nr.** | **Tool name** | **NL** | **LC** | **HU** | **RV** | **IT** |
| 1 | pirimicarb | 3 | 2 | 4 | | 2 |
| 2 | thiacloprid | 3 | 4 | 4 | -1 | 1 |
| 3 | imidacloprid | 2 | 1 | 4 | | 2 |
| 4 | flonicamid | 1 | 3 | | -1 | 1 |
| 5 | thiamethoxam | | | | | 1 |
| 6 | acetamiprid | | | | -1 | 1 |
| 7 | clothianidin | | | | | 1 |
| 8 | azadirachtin (Neem)* | 2 | 2 | | | 2 |

### *Powdery mildew – PODOLE (Podosphaeraleucotricha)*

Powdery mildew is favored bywarm periods with high humidity of the air as we (might) have them in the apple regions of NL, LC, and HU. In LC, the chemical control of scab is done in combination with mildew. This is the reason why the appearance of mildew is here rather low (pest rank1). The list of major pesticides is presented in Table 3.7a. To complement the apple protection two major non-chemical tools are currently applied (Table 3.78b). First of all clean pruning of infected branches and twigs, starting in winter and continuing in spring and eventually in summer. The secondmethod is the use of resistant cultivars. Besides Elstar new resistant cultivars are,for instance,Rewana, Regine, Remo, Regia, and Rebella. However, their taste is not very popular and due to their poor acceptance by consumers growers prefer other cultivars.

**Table 3.7a.Use of fungicide against powdery mildew in the NL, LC, HU, RV and IT region. Figures show the rank per region.A blank field means no application, i.e. = 0.**

| | | Apple regions | | | | |
|---|---|---|---|---|---|---|
| **Tool nr.** | **Tool name** | **NL** | **LC** | **HU** | **RV** | **IT** |
| 1 | penconazole | 2 | 3 | 2 | 4 | 2 |
| 2 | trifloxystrobin | 2 | 2 | 3 | | 2 |
| 3 | myclobutanil | | 3 | 3 | | 2 |
| 4 | bupirimate | 3 | -1 | | 4 | 2 |
| 5 | triadimefon | 2 | -1 | | -1 | |
| 6 | kresoxim_methyl | 2 | | | -1 | 2 |
| 7 | boscalid, pyraclostrobin | | | | -1 | 5 |
| 8 | difenoconazole | | 1 | | -1 | 2 |
| 9 | tebuconazole | | | | -1 | 2 |
| 10 | fenbuconazole | | -1 | | -1 | 2 |
| 11 | tetraconazole | | -1 | | -1 | 2 |
| 12 | quinoxifen | | -1 | | -1 | 2 |
| 13 | sulphur | 1 | 5 | -1 | 4 | 5 |

**Table 3.7b. The importance of non-chemical tools against powdery mildew in the NL, LC, HU, RV and IT region. Figures show the rank per region.A blank field means no application, i.e. = 0.**

| Category | Tool nr. | Tool name | Apple regions | | | | |
|---|---|---|---|---|---|---|---|
| | | | NL | LC | HU | RV | IT |
| CM | 1 | winter/spring clean pruning | 2 | 4 | 4 | 2 | 4 |
| | | | | | | | |
| PR | 2 | cultivar resistance | | | | 1 | |

### *San Jose scale –QUADPE (Quadraspidiotusperniciosus)*

In Europe, San Jose scale is a minor pest(rank1 for HU, LC and unknown in NL). But with the global warming this might change. Mineral oil is the major control tool. In Hungary, mineral oil applications are rather frequent (tool rank 4); its application in LC is low -medium and in NL unknown.In LC as in the USA, predators and pheromone traps are known for fruit protection against San Jose scale, next to insecticides. For instance,*Encarsia perniciosi*has the potential to reduce the population of San Jose scale. Nevertheless the infestation with San Jose scale increased during the last years in the fruit production region LC.

## 3.3 Control methods per pest in pear orchards

### *Brown spot of pear –PLEOAL(Stemphylium vesicarium)*

It was found that brown spot causes crucial problems in the region IT (pest rank 3b) and NL (rank 2), few damage in RV and none in LC and HU (Table 3.1). The set of elements for pest control covers besides fungicide all alternative categories: DSS, cultivation and mechanical measures, bio-control and resistant cultivars. While in the Netherlands the pest control relies on chemical tools, the focus in IT is on non-chemical control. Here, the pear infection occurs all season long and farmers usually spray 15 to 30 times to counteract fruit damage. The use of pesticides could be reduced by 30 to 40% through alternative methods as adequate cropping practices that lower the infection efficiency. The registration of thiram was recently stopped in the Netherlands (January 2012).

*Descision support – DSS*

In IT, DSS is highly used to identify the onset of spraying and the optimum treatment dates. DSS is an interactive process between farmers, who provides field information (monitoring of the disease), and extension persons, who integrate all information by means of the BSPcast forcasting model (ENDURE-Deliverable DR1.8 & DR1). The model results are transferred to the farmers. In NL DSS is recently introduced and used at a limited scale.

*Cultivation and mechanical Control – CM*

In IT sanitation is considered, although very few farmers take care of sanitation, like leaf litter removal, when the pest problem is severe. Furthermore affected branches are removed and burned as well as autumn leaves (Llorente at al. 2010).

**Table 3.8a.Use of fungicide against brown spot of pear in the NL, LC, HU, RV and IT region. Figures show the rank per region. * indicate tools allowed in organic farming.A blank field means no application, i.e. = 0.**

| Tool nr. | Tool name | Apple regions | | | | |
|---|---|---|---|---|---|---|
| | | NL | LC | HU | RV | IT |
| 1 | thiram | | | | 2 | 2 |
| 2 | captan | 5 | | | 2 | 2 |
| 3 | trifloxystrobin | 3 | | | 2 | 2 |
| 4 | difenoconozole | 3 | | | | |
| 5 | kresoxim-methyl | 3 | | | | |
| 6 | penconazole | 1 | | | | |
| 7 | ciprodinil+fludioxonil | | | | 2 | 2 |
| 8 | tebuconazole | | | | | 2 |
| 9 | boscalid+piraclostrobyn | | | | | 2 |
| 10 | fludioxnil + ciprodinil | | | | 2 | |
| 11 | copper* | | | | 2 | 2 |

**Table 3.8b. The importance of non-chemical tools against brown spot of pear in the NL, LC, HU, RV and IT region. Figures show the rank per region.A blank field means no application, i.e. = 0.**

| Category | Tool nr. | Tool name | Apple regions | | | | |
|---|---|---|---|---|---|---|---|
| | | | NL | LC | HU | RV | IT |
| DSS | 1 | descision support system | 1 | | | | 3 |
| | | | | | | | |
| CM | 2 | sanitation | | | | | 2 |
| | | | | | | | |
| BC | 3 | trichodermaspp | | | | | -1 |
| | | | | | | | |
| PR | 4 | cultivar William | | | | 4 | 4 |
| PR | 5 | cultivar Morettini | | | | | 4 |
| PR | 6 | cultivar Spadona | | | | | 4 |

*Biocontrol–BC*

The biocontrol method with the antagonist *Trichoderma spp*. is still in the testing phase and not yet a common practice in the IT region(Rossi & Pattori 2009).

*Resistant cultivars – PR*

Resistant cultivars seem to be considered as a useful way to handle brown spot by Italian pear growers. With the exception of IT, market aspects rather than pest problems drive the cultivar choice (ENDURE-Deliverable DR1.8 & DR1).

### *Pear psylla–PSYLPI (Cacopsylla pyri)*

Pest psylla occurs frequently in the regions NL, LC and to some extent in RV (all pest rank 3b). The problem is less severe in Italy (pest rank2).Pear psylla is characterized by a multiple generations and high reproduction. Moreover, the development of pesticide resistance is rapid). In Germany,the pest control depends on insecticide, but in the other regions most of all in NL and IT biocontrol is integrated in the pest management.Pear psylla damage is reduced by a predator of the bug family Anthocoridae in Italy, Lake Constanceregion and the Netherlands.Growers in LC try to preserve this predator by choosing the right chemicals. Kaolin is an alternative insecticide for IPM and organic farms; when applied prior to flowering the pest can be kept below the threshold level for the entire season. Kaolin is not toxic to other insects than pear psylla and is used for this in NL, LC and RV. In the region, LC and NL, the result of kaolin was not satisfactory, since it was not completely effective.Dutch, Italian and most of all French growers consider mineral oil as important control measure.

**Table 3.9a.Use of inseticide against pear psylla in the NL, LC, HU, RV and IT region. Figures show the rank per region. * indicate tools allowed in organic farming.A blank field means no application, i.e. = 0.**

| Tool nr. | Tool name | Apple regions | | | | |
|---|---|---|---|---|---|---|
| | | **NL** | **LC** | **HU** | **RV** | **IT** |
| 1 | abamectin | 4 | 4 | 4 | 5 | 4 |
| 2 | spirodiclofen | | 4 | 4 | | |
| 3 | deltamethrin | 2 | | | | |
| 4 | spirotetramat | 2 | | | | |
| 5 | imidacloprid | 2 | 1 | | | |
| 6 | mancozeb | 2 | | | | |
| 7 | fenoxycarb | | | 2 | | |
| 8 | kaolin* | 2 | 1 | | 2 | |
| 9 | oil* | 3 | | | 5 | 4 |

It is striking that pear psylla occurs much less in organic farms and is absent in abandoned orchards. This suggests that tree vigor and natural enemies might be key control measures, which should be possible to found in abandoned and organic pear orchards. It is still unclear which natural enemies should/ could be promoted to control efficiently pear psylla. Examples of natural enemies are Anthrocoris nemoralis and earwigs. Anthrocoris nemoralis can migrate from the landscape (trees, shrubs) and hedgerow into the pear fields. The occurrence of earwigs depends on orchards management, i.e. the avoidance of certain chemical ingredients. However, the control of other pests, e.g. codling moth often interferes with the natural control of pear psylla. Another non-chemical method to keep psylla number slow is the reduction of tree (shoot) growth by limiting nitrogen applications, applying growth regulators and summer pruning.

**Table 3.9b. The importance of non-chemical tools against pear psylla in the NL, LC, HU, RV and IT region. Figures show the rank per region.A blank field means no application, i.e. = 0.**

| Category | Tool nr. | Tool name | Apple regions | | | | |
|---|---|---|---|---|---|---|---|
| | | | **NL** | **LC** | **HU** | **RV** | **IT** |
| BC | 1 | conservation biocontrol | 3 | | | 1 | |
| BC | 2 | anthocoridae | 3 | 1 | | | 3 |
| | | | | | | | |

### *Pear bedstraw- DYSAPI (Dysaphis pyri)*

The aphid pear bedstraw caused regularly damages of economically importance in all regions, i.e. NL,LC, RV, IT (pest rank 2). Non-chemical tools are apparently not applied. At present mineral oil and kaolin, which are the insecticides for IPM and organic farming practices.

**Table 3.10.Use of insecticideagainst pear bedstraw in the NL, LC, HU, RV and IT region. Figures show the rank per region. * indicate tools allowed in organic farming.A blank field means no application, i.e. = 0.**

| Tool nr. | Tool name | Apple regions | | | | |
|---|---|---|---|---|---|---|
| | | NL | LC | HU | RV | IT |
| 1 | flonicamid | 3 | 4 | | 4 | 3 |
| 2 | acetamiprid | 1 | | | 4 | 3 |
| 3 | pirimicarb | 3 | | | 1 | |
| 4 | thiacloprid | | 4 | 3 | | |
| 5 | imidacloprid | 1 | | | 3 | |
| 6 | fluvalinate | | | | | |
| 7 | pimetrozine | | | | | |
| 8 | fluvalinate | | | | 3 | |
| 9 | pimetrozine | | | | 3 | |
| 10 | pyrethines | | 2 | | 1 | |
| 11 | oil* | 2 | | | 5 | |
| 12 | kaolin* | | | | 2 | |

### *Pear scab- VENTIN (Venturia pirina)*

Pear scab is very similar to apple scab and caused by a related fungus. Hence, the same fungicide and control measures applied for apple scab will be also effective against pear scab. In pear scab, the number of required treatments is lower, since the pest severity is usually less. In RV the pest pressure is low, but increasing. The problem in Germany and the Netherlands, where apple scab is a huge problem pear scab problem is only medium severe (pest rank2), while in IT the pest pressure is highest.

**Table 3.11. Use of fungicide against pear scab in the NL, LC, HU, RV and IT region. Figures show the rank per region. * indicate tools allowed in organic farming. A blank field means no application, i.e. = 0.**

| Tool nr. | Tool name | Apple regions | | | | |
|---|---|---|---|---|---|---|
| | | NL | LC | HU | RV | IT |
| 1 | thiram | | | | | 3 |
| 2 | trifloxystrobin | 2 | 1 | 3 | | |
| 3 | dithianon | 4 | 4 | 4 | | |
| 4 | captan | 5 | 4 | 4 | | |
| 5 | cyprodinil | 3 | | | | 3 |
| 6 | boscalid | | | | | 3 |
| 7 | pyraclostrobin | | | | | 3 |
| 8 | etiram | | | 2 | | 3 |
| 9 | fenbuconazole | | | | | 3 |
| 10 | penconazole | | | | | 3 |
| 11 | difenoconazole | 2 | | | | 3 |
| 12 | tetraconazole | | | | | 3 |
| 13 | pyrimethanil | 1 | | | | 3 |
| 14 | kresoxim-methyl | 2 | | | | |
| 15 | fludioxinil | 2 | | | | |
| 16 | mancozeb | 2 | | | | |
| 17 | dodine | 1 | | | | |
| 18 | sulphur* | 3 | 5 | 3 | 4 | |
| 19 | lime sulphur* | | | 3 | | |
| 20 | copper* | | | | 4 | 3 |

## 3.4Novel tools

The results of the data queries for major pest control tools in European pome fruit confirm that alternative methods are still of minor importance. Obviously, farmers prefer synthetic pesticidesbecause they are easy to handle and economically more interesting. For the data analysis we suppose that the toolsgiven the rank -1 (= unknown) are most likely to be new and not yet (much) introducedin practice, since otherwise they would be known. In this paragraph, alternative methods that still have to find their way into practice are described briefly.Many of them are also listed in the tables above others have been identified during a WP5 meeting in Wageningen, 25. February 2012.

### 3.4.1 Apple scab

There are many non-chemical tools for the control of apple scab, but its implementation is difficult due to their moderate efficacy, which explains thatmany tools in Table 3.3bgot rank -1 (i.e. unknown) and 0 (not applied). Two alternative main strategies are possible: a) lower the susceptibilityby choosing resistant cultivar and b) decreasing the pest pressure. The use of resistant cultivars could be motivated in northern Europe, by finding cultivars that are pest resistant and satisfy consumers taste. During the PURE WP5- meeting in Wageningen (25 Feb. 2012) goal tools were gathered,from which some are already in practice. For instance, the pest pressure canbe reduced by:

- removal of overwintering inoculum with the litter removal, mulching, ploughing in, shredding and pruningof one year old woody shoot

- using earthworm prior to leaf removal
- fertilization with calcium cyanamideand/or urea prior to bud break will reduce the potential of ascospore
- minimum input of the pesticide cercobin will increase the earthworm population, which in turn decrease the ascospore potential
- sprayingof potassium bicarbonatein combination with copper or sulphur.

Further goal tools are:

- urea application during winter in NL and spring in LC leads to ascospore reduction
- BCA during winter and growing season
- omit first spray in the season based on PAD threshold values
- develop warning system (e.g. RIMPRO, "Schorf")

### 3.4.2 Codling moth

Insecticide application could be restricted to periods when population around traps is important. That meansspraying actions shouldbe based on trap catches.

The use of pheromones for mating disruption could be improved for most of the regions and then become a promising alternative to insecticides. In the LC region, the applied pheromone techniqueis working well.

Exclusion netting of the pest is an innovative tool which is still under development, particularly in RV, provided there is no detrimental effect of the nets on the control of other pests or fruit yield (recent program in progress, experiments in Avignon and Valence in the frame of a project supported by the French Ministry of Environment ONEMA (the French national agency for water and aquatic environments) in the frame of the project call "pesticides impacts and limitations" year 2011). Exclusion nets also provide protection against hail, wind damage, birds and sun burn spots. Further studies on the impact of nets as a control measure is required also in northern Europe.

Currently, providing shelter for the predator *Forficula auricularia* (earwig) is tested. It might help against codling moth and wooly aphids at the same time.

### 3.4.3 Pear psylla

In southern Europe, growth regulation is mentioned as a good tool for pest control, whereas, in the north it is seen as conflicting with the aim of a high level of fruit production.Root pruning is a new method to lower growth vigor. Other goal tools are:

- accompanying vegetation that is beneficial for natural enemies (earwig and anthorcoridae), e.g. nettles, hedges including Salix (a tree with an early nectars and pollen as an alternative food source)
- Monitoring and treating when pest is a problem
- Overhead irrigation
- Pear psylla tolerant root stocks
- Natural products: soap for washing trees ( it takes off the honey dew), potassium nitrate

### 3.4.4 Brown spot of pear

According to Rossi (pers. comm. Feb. 2012) the use of pesticides could be reduced heavily through cropping practices that either lower pest infestation, e.g. irrigation, fertilization, pruning, leaf litter removal and thus removal of overwintering inoculum in the litter (Llorente et al. 2010). Additionally, the use of biological control agents, such as formulates of *Trichoderma spp*. could be beneficial in terms of crop protection (Patorri et al. 2007).

# 4. SUMMARY and CONCLUSION

The key pests, major tools including non-chemical measures identified from PESAP queries are presented in Chapter 3.The severity of the various pests differs in correspondence with the specific ecological situation of the region. According to earlier investigations, the climatic North-South gradient is reflected in the pest problems and control strategies (Buurma 2010). Overall, the results reveal low adoption of non-chemical tools like “granulosisvirus, mating disruption and sanitation” as was already found during ENDURE. Consequently, there is still a high potential to the reduction of pesticide application.The existing innovative, non-chemical tools as well as new effective methods have still to find their way into practice. This requires the implementation of the single tools into a complete pome fruit management strategy and the education of growers. The elements of such strategies (i.e. single alternative tools), collected in PURE and described here, can be synthesized to two main objectives/categories of sustainable fruit tree protection.

Both objectives make usually part of what is called “good farming practices”, nevertheless they are not considered as crop protection by most farmers.For instance in a survey in Germany only few farmers’ mention CM tools. However, many of the cultivation and mechanical (CM) tool can have a positive impact on crop protection.

Firstly, the grower should focus on healthy and robust tree material. This starts withthe planting material:strong, healthy trees and cultivars that are adapted to the local conditions, including resistance/ tolerance to local pests should be chosen.There is a lack of cultivars that match producers’ (productive, pest resistant) and consumers’ wishes (quality)in NL and LC and generally for codling moth and pear psylla. Over the tree life cycle, the cultivationactions should guarantee a good fruit production whilemaintaining the trees healthy. Accordingly, the tree vigor and shoot growth should be kept on an optimum level through pruning (root and shoot), adequate fertilization and irrigation. The latteractions conflict with the desired high level of fruit production in the northernregions.

Secondly, the pest pressure should be kept at a low levelby alternative means as much as possible. This can be achieved most effectively, when pest monitoring and DSS are regarded for timing and degree of control actions.The removal of infected material through sanitation measures and natural enemies and the pest exclusion by nets and a year “fruit stop” need further studies. Their effects need to be better understood and quantified, before they can fit into pest management.

An ideal IPM would be a strategy that relies mainly on these two objectives, completed with BCA and natural chemicals and only the remaining “pest problem” would be counteracted with synthetic chemical pesticides. Moreover, the ideal strategy, in terms of sustainability would comprise all major pests, since some actions are working for several pests while others are conflicting.

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