POMEFRUIT
« Results and lessons learnt from PURE »

FEBRUARY 2015

OBJECTIVES of Work Package5

Objective of Work Package 5 is to develop innovative integrated pest management (IPM) methods for pome fruit and to stimulate the uptake of these methods into practice. More specific, the objectives are:

1. To develop new methods or strategies as part of a complete IPM system.
2. To demonstrate the environmental and economic effects of the IPM innovation.
3. To test innovative IPM strategies on durability in practice.
4. To stimulate and promote uptake of innovative IPM methods into practice.

PESTS and APPROACH (EXPERIMENTS, ASSESSMENT TOOLS, …)

On-farm and **on-station** experiments have been conducted on the main pests and pathogens in Europe. In this report, you'll find information on the tested innovative control methods against pear psylla and pear brown-spot, and for apple, on codling moth and scab.

INNOVATIVE METHODS from other Work Packages

Intense interaction between WP 11 "Emerging technologies" and WP 5 "Innovative IPM in pome fruit systems" took place for precise sensing and canopy adapted spraying methods. Both on-farm testing and stakeholder interaction resulted in interest from a commercial company to participate in further development.

Stakeholder interaction with fruit growers on precise sensing and canopy adapted spraying

LIMITS AND CONDITIONS OF SUCCESS, ADAPTATIONS

Innovative and new IPM tools were tested under well-defined conditions in experimental orchards. Subsequently, they were tested in commercial orchards as part of a complete IPM system where drawbacks and bottlenecks become clear. In on-station experiments the drawbacks or bottlenecks were solved and adjusted IPM tools were again tested in commercial orchards. It became clear that this so-called "design – assessment – adjustment cycle" needs more time than available within the time frame of the PURE-project. Time needed for development of new techniques in pillar 2 is also restricting uptake of these methods in pillar 1 work packages.

Some of the results from ex-post assessments, especially the cost-benefit analyses, showed that innovative IPM methods in pome fruit sometimes took more labour and/or higher costs. Even with intense stakeholder interaction uptake of those new IPM techniques then becomes hampered.

Pomefruit – Pear psylla control
« Results and lessons learnt from PURE »

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OBJECTIVES

Specific objectives for pear psylla control

- To learn which pesticides have negative side effects on common earwig, an important predator of pear psylla.
- To develop an IPM strategy with adequate efficacy against all pests and at the same time without negative side effects on natural enemies.
- To test the innovative IPM strategy in commercial pear orchards.
- To promote uptake of the innovative IPM approach.

APPROACH (EXPERIMENTS, ASSESSMENT TOOLS, …)

Key elements of the approach to reach **the objective for pear psylla control** are:

On-research station experiments:

1. Test negative side-effects of pesticides (insecticides, fungicides and herbicides) on natural enemies of pear psylla.
2. Assemble a full season pesticide spray schedule without negative side-effects.

On-farm experiments:

3. Test the sustainable pesticide spray schedule in practice.
4. Organise stakeholder meetings.

PESTS

Pear psylla (pear sucker) - Cacopsylla pyri : Picture of different stages.

Eggs of pear psylla

Young nymph

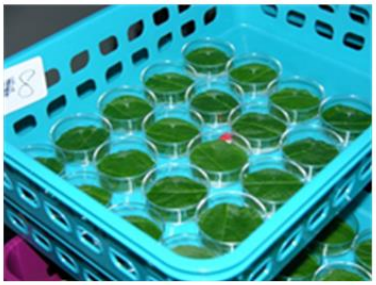
Nymph

Adult pear psylla

TECHNICAL RESULTS

Exposure to pesticide residues on bean leaves showed that none of the fungicides and leaf fertilisers had negative side effects on common earwig (*Forficula auricularia*), one of the important natural enemies of pear psylla (see following pictures). However, some insecticides such as indoxacarb, neonicotinoids and pyrethroids had negative side effects on earwigs. And female earwig exposed to residue of the herbicide amitrol deposited eggs, but these eggs died and no offspring was produced (details in Helsen & Booij, 2013).

Paralysed earwigs after exposure to a neonicotinoid insecticide



Bean leaves with residue of pesticides for exposure of earwigs

A study group of pear growers was formed and winter meetings with growers, advisors and researchers were organised. Biology of the pest and possibilities of innovative control were discussed. Together with the growers, an innovative control program was discussed and agreed upon for implementation. Growers chose to implement a selective pesticide scheme to avoid undesired side effects on natural enemies. Psylla populations were followed throughout the season and advice was given on the necessary crop protection measures. The density of the main predator, the common earwig *Forficula auricularia*, was measured in each of the fields. Just before harvest a qualitative assessment of the fruit quality was made.

Discussion on pear psylla control with fruit growers

Results showed that yield quantity was not affected by the innovative IPM system compared to the standard system. Growers didn't notice any difference in yield quality either. However, research observations showed a minor, non-significant reduction in yield quality, mainly through black smut fungi growing on honey dew from pear psylla on the surface of pears. Consequently, there was a slight shift in the portion of yield from class I pears towards class II pears. On the other hand the substitution of pesticides with side effects on beneficial insects (innovative compared to standard) might enhance the price security in the market.

SUSTAINABILITY OF IPM SOLUTIONS

Compared to the standard system, the full season innovative IPM strategy substantially reduced both acute and chronic **environmental risk** as calculated by the assessment model SYNOPS-WEB (table below).

	Aquatic	Terrestrial	Groundwater
Acute risk			
Standard	18.291	0.263	32.654
Innovative	0.003	0.001	0.000
Chronic risk			
Standard	34.079	2.375	6.531
Innovative	0.022	0.000	0.000

Cost-benefit analyses of this situation demonstrated that gross yield of the innovative IPM system was lower than the standard system. Moreover, costs of IPM measures were slightly higher in the innovative system compared to the standard system. As such, returns were € 2250/ha lower in the innovative IPM system than in current practice.

LIMITS AND CONDITIONS OF SUCCESS, ADAPTATIONS

The strategy depends on the availability of selective methods and/or products for weed, disease and insect control in general without negative side-effects on natural enemies.

As numbers of natural enemies slowly increase under an IPM regime, their contribution to the psylla pest control will grow over years.

REFERENCES	Helsen, H. and Booij, C. 2013 Effects of amitrole (3-amino-1,2,4-triazole) on the common earwig *Forficula auricularia* L. (*Dermaptera: Forficulidae*). IOBC-WPRS Bulletin Vol. 91:143-146.

Innovative management of brown spot in pear orchards
« Results and lessons learnt from PURE »

FEBRUARY 2015

OBJECTIVES

The climatic conditions of the Po Valley are often favourable for brown spot of pear caused by the fungus *Stemphylium vesicarium*. This disease represents a major threat for growers and requests 15-25 sprays/year, to avoid yield losses that could reach 50-60%.

The **specific objective** of this task was to reduce the overwintering inoculum of the fungus and to rationalize the fungicides schedule necessary to control disease development.

APPROACH (EXPERIMENTS, ASSESSMENT TOOLS, …)

The approach carried out in the experimental sites to design advanced IPM orchards is based on the integration of:

1. degradation of the leaf litter where the pathogen overwinters and sporulates to reduce the inoculum, provided by biocontrol agents, and the

2. reduction of the number of treatments by Decision Support System (DSS) for scheduling fungicide applications.

PESTS

Brown spot – Stemphylium vesicarium

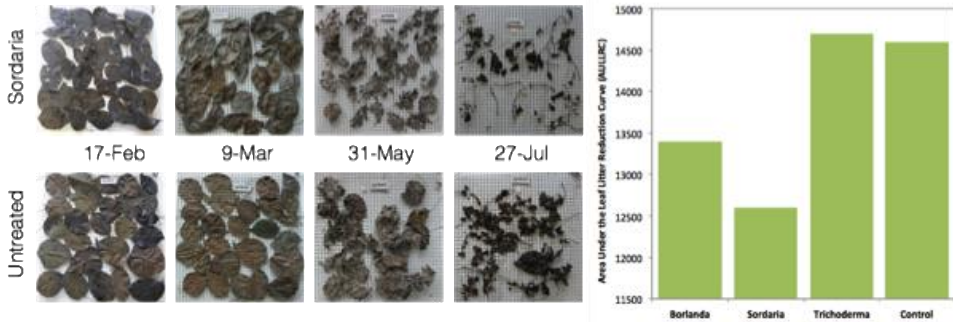
Leaf symptoms caused by *S. vesicarium*

Symptoms caused by *S. vesicarium* on pear

TECHNICAL RESULTS

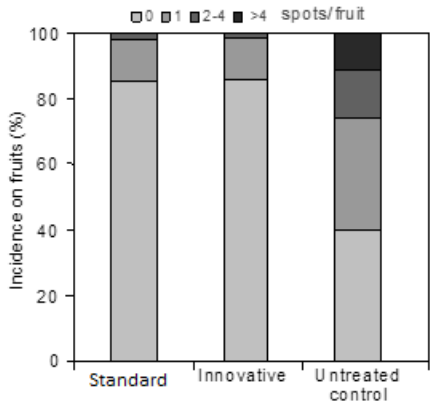
In **on-research station** experiments, different combinations of vinasse, *Sordaria fimicola* and *Trichoderma* sp. were tested on cv. Conference leaf litter: leaf litter samples were treated at the end of the winter and the amount of leaf residues and the speed of degradation were assessed at regular intervals by means of an image analysis software until early August. The application of *Sordaria* sp. caused a quicker and higher degradation of the leaf residues compared to untreated control. This result is relevant in order to reduce the inoculum of *S. vesicarium* during winter time.

On-station experiments: on the left, comparison between degradation of the overwintering leaf litter in an untreated (Control) and in leaves treated with *Sordaria* sp.; on the right, the amount of the leaf litter residues remaining at the end of the experiment (early August)



In **on-farm** experiments, two systems were compared: i) a standard system, representing the average of a large production area in North Italy, and ii) an innovative IPM system where the use of a Decision Support System (DSS) for scheduling fungicide applications was combined with leaf litter removal and periodical applications of Biological Control Agent (BCA, commercial formulates of borlanda and *Trichoderma* spp.). The experiments were replicated in 2013 and 2014 on cv. Conference and Abate-Fetel, both very susceptible to brown spot. The results were promising because the disease was similar in the innovative IPM system and in the standard, but there was a 50% reduction in terms of pesticide usage.

On-farm experiment: comparison between brown spot on fruits in the standard, innovative IPM and untreated control



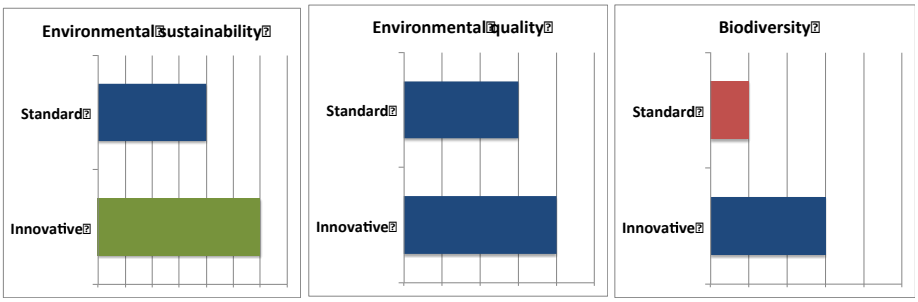
SUSTAINABILITY OF IPM SOLUTIONS

Over two seasons, the fungicide schedule for controlling brown spot on pear of the Innovative approach was reduced, on average, by 64% compared to the Standard practice.

The **environmental sustainability** of the Innovative approach was significantly higher compared to Standard, mainly because of a better ecotoxicological profile of the pesticides used that showed a reduced impact on biodiversity of the orchard and permitted to enhance its environmental quality (see following graphs).

The innovative IPM system showed the potential of obtaining an effective and environmental friendly control of brown spot on pear.

Sustainability assessment of Standard and Innovative brown spot management performed with DEXiPM over two seasons (2013-2014) in North-Italy



The total production of pears obtained in the two systems was more or less similar during the two seasons. In 2013, the gross yield obtained from the production was lower in the innovative system because of -4 % production of premium quality fruits. In 2014, two sites were tested, and the average yield was 2% more in the innovative system because of the low level of disease observed in field. In any case, the costs of DSS application were earned back through reduction of fungicide sprays (2014). Innovative system gave 2% higher gross yields in case of low infection pressure (2014).

Seasonal differences in terms of weather conditions, with particular emphasis to rainfall, and thus risk of disease onset and development produced different results in terms of yield and remuneration of the grower.

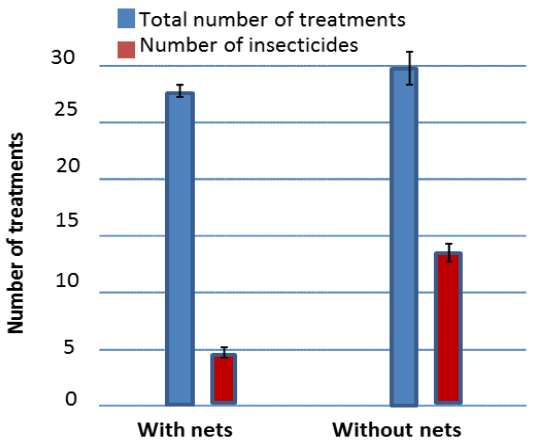
The impact of the innovative IPM system increased the **overall sustainability** of the complete orchard system to “very high”.

LIMITS AND CONDITIONS OF SUCCESS, ADAPTATIONS

The overall sustainability of the standard system, in the case study observed during PURE, can be considered of “high” quality. In many cases, the standard is the current application of IPM at present and thus, a further improvement, may only result in a little increase of the sustainability of the system.

The innovative tools tested showed that a further improvement of the environmental quality is possible, with efficient disease control. Higher costs of implementation of the innovative approach are compensated in case of low disease level through a saving in fungicide applications and an increased top quality production.

	CROPPING SYSTEM NAME: Apple – codling moth **« Results and lessons learnt from PURE »** FEBRUARY 2015
OBJECTIVES	Fruit trees require the application of 7-15 insecticides specifically targeting the codling moth (*Cydia pomonella*). Exclusion netting, as a physical control tool, prevents this pest to reach the trees. This tool potentially replaces all the treatments against this key-pest. There are two forms for this netting, either "single-row" system (net covered each row) and the "whole-orchard" system (a modification of anti-hail system). The **specific objectivewas** to evaluate the integration of such innovative IPM tools into advanced fruit production strategies.
APPROACH (EXPERIMENTS, ASSESSMENT TOOLS, …)	Effects of nets on the orchard microclimate, the agronomic performances and other pest complex (fruit damage and infestation levels), including the rosy apple aphid (*Dysaphis plantaginea*), were studied under different management strategies **in research station** experiments. **On-farm** experiments were conducted in the "Alt'Carpo" network composed of 17 netted and 13 uncovered commercial apple orchards under either organic or IPM management.
PESTS	***Cydia pomonella* (Codling moth)** Adult and larvae within an apple  
TECHNICAL RESULTS	In the French **on-farm network**, the 'single-row' netting system enabled a significant reduction in pesticide use without any major risks for the production. Insecticide use was reduced from 13.7 equivalent full-dose treatments down to 4.1 with net, while fungicide use remained similar (13.4 treatments without vs 14.8 with net).



Effect of exclosure netting on the treatment number (on-farm network).

In **on-station** experiments, no significant modification of the tree growth or architecture, neither of fruit quality and orchard yield was observed. Harvest date was delayed of a few days under nets, most probably because the climate under nets was significantly but little modified with for example a slight decrease in PAR (Photosynthesis Active Radiation).

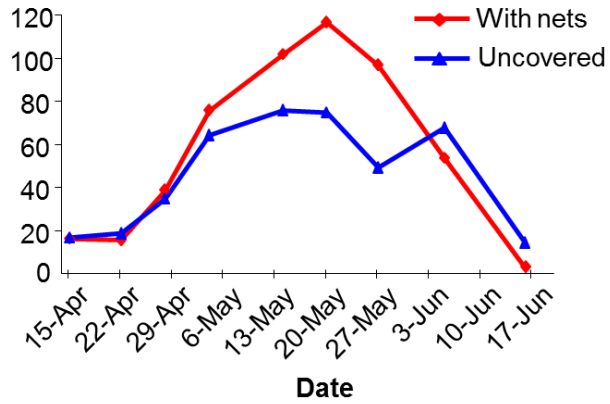


Figure 6. Mean rosy apple aphid number per shoot (total)

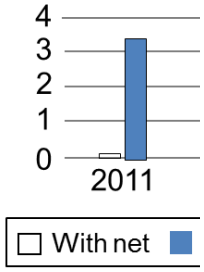


Figure 7. Percentage of dam
C. pomonella* and *G. molest

(a) **On-station** data (b) **On-farm** data.

In **on-station** experiments, the mean number of rosy apple aphid was higher under the nets probably because some natural enemies (such as Cocinellidae) cannot reach the aphid colonies. Conversely, codling moth and other Lepidoptera (e.g. fruit Tortricidae) were highly controlled.

SUSTAINABILITY OF IPM SOLUTIONS

Our work revealed that the **overall sustainability** of orchards covered by exclusion netting was higher than non-covered orchards. This was due to (i) exclusion netting has economic advantages when hail damage risk is higher than 10% (the cost of netting includes the devices and labour to open and close it) and (ii) a higher environmental sustainability related to a reduced use of insecticides and notably organophosphate insecticides. This resulted in a general improvement for both acute and chronic risk. Netting also permitted an important reduction in the impact of crop protection on both terrestrial organisms and pollinators (bees) (see Table below).

Levels of acute and chronic* risks due to pesticide use in the standard and the netted innovative cropping systems tested in France in 2013 against codling moth.*

	Aquatic	Earthworm	Bee
Acute risk			
Without net	466.417	0.045	8.157
Netting	55.970	0.084	0.014
Chronic risk			
Without net	39.664	0.435	55.940
Netting	8.790	0.822	0.157

**Acute=short-time exposure and chronic = continuous or repeated exposure*

INNOVATIVE METHODS

With WP1, we contributed to the development of an assessment tool to ex ante test the effect of the use of different IPM tools on codling moth damage and associated yield loss.

LIMITS AND CONDITIONS OF SUCCESS, ADAPTATIONS

We recommend using the 'single-row' version of netting, which is, up to now, more efficient than the 'whole-orchard' version.

Due to the cost and constraints of netting, this method is to be privileged in areas where codling moth is difficult to control and/or where a double aim of anti-hail protection and codling moth control is targeted.

Tree training and shape also have to be adapted to netting, above all for single-row nets that envelop the row canopy.

Last, although the method is highly efficient, observations of orchard pests and diseases are still necessary to manage the crop protection: reduction in pesticide use can induce an increase in some other pests, requiring the application of specific insecticides in some cases.

REFERENCES

Marliac G., Simon S., Fleury A., Alaphilippe A., Dib H., Capowiez Y. (2013) Contrasting effects of codling moth exclusion netting on the natural control of the rosy apple aphid. IOBC Bull. 91:81-85

Innovative fungal management of apple scab in apple orchards
« Results and lessons learnt from PURE »

FEBRUARY 2015

OBJECTIVES

Climatic conditions in Hungary are suitable for disease development, including apple scab caused by the fungus *Venturia inaequalis*. In susceptible apple cultivars yield loss can range between 40-70% in Hungary. Apple scab can be controlled with 12-20 chemical sprays annually.

The **specific objective** of this task was to test innovative control options in order to reduce inoculum sources of apple scab and if possible to reduce the number of chemical sprays against the disease.

APPROACH (EXPERIMENTS, ASSESSMENT TOOLS, …)

A small scale (**on-station**) and a large scale (**on-farm**) experiments were conducted comparing three protection strategies:

1. Standard (spray with fungicides and insecticides and warning system) ;
2. IPM1 (leaf removal + fungicide + insecticide sprays with mating disruption) ;
3. IPM2 (Leaf removal + pruning + insecticide sprays (mainly granulosis viruses, Bt) with mating disruption.

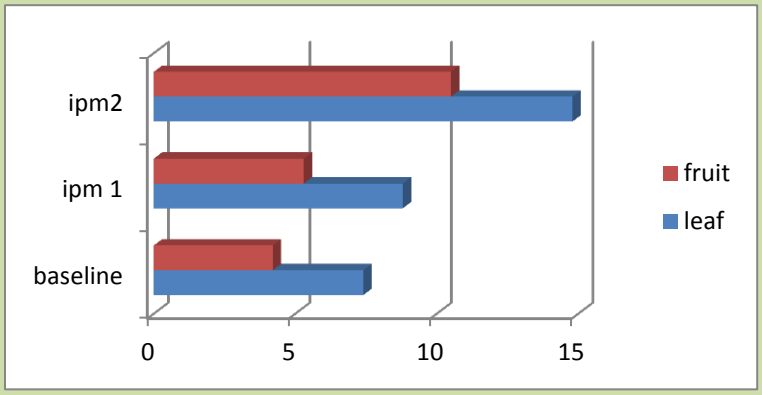
On-station treatments were done in 5 replicates (10 trees per replicate, assessment on middle 6 trees).
On-farm treatments were replicated three times (each field 0.5 ha, assessment within each replicate 5 replicates of 6 trees).
For both on-station and on-farm, fruit and leaf scab were assessed. Assessment was made on 6 x 200 leaves and 6 x 25 fruits /replicate.

PESTS

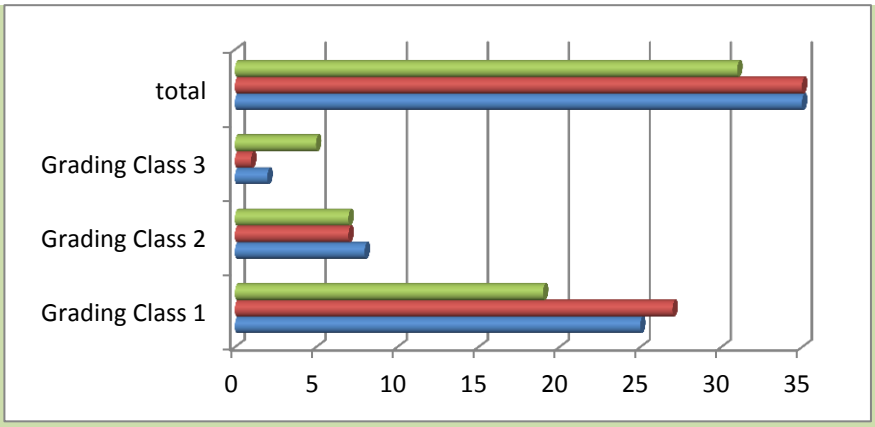
Apple scab – Venturia inaequalis (sexual form), Spilocaea pomi (asexual form)

TECHNICAL RESULTS

Results from **on-station** experiment showed that leaf and fruit scab incidences were the largest in the most innovative system of IPM2. Yield was the highest in standard and IPM1 systems. Fruit grading class I was the highest in IPM1.



Scab incidence (percentage) on fruit and leaf in the different production systems



Yield (t/ha) and fruit grading for the different produciton systems (blue: standard, red: ipm1; green: ipm 2).

Results from **on-farm** experiment supported results of the on-station experiments. Leaf and fruit incidences were the highest in the most innovative systems of IPM2 with 16.5% and 9.9% (leaf and fruit scab incidence, respectively). Yield was the highest in standard and IPM1 system. Fruit grading class I was the highest in IPM1 and standard systems (21 t/ha out of the total of 31t/ha).

Overall IPM 1 is the best for scab control and yield aspect with autumn leaf removal in order to reduce primary inoculums of the disease.

SUSTAINABILITY OF IPM SOLUTIONS

The **environmental risk**, assessed with SYNOPS-WEB, on aquatic organisms was mostly due to one specific active ingredient (dodine) in all three systems. The innovative system allowed an improvement in both acute and chronic risk for earthworms and bees because of the reduced usage of this active ingredient (table below).

Levels of acute and chronic* risks due to pesticide use in the baseline, IPM1, IPM2 cropping systems tested in Hungary in 2013 against apple scab.*

	Aquatic	Earthworm	Bee
Acute risk			
Baseline	3.55	0.0025	0.0074
IPM 1	3,54	0.0044	0.0024
IPM2	3.56	0.0045	0.0023
Chronic risk			
Baseline	1.841	0.090	0.069
IPM1	1.72	0.069	0.025
IPM2	1.71	0.068	0.018

Concerning the **cost-benefit** analysis, leaf removal (IPM 1) resulted in both higher physical yields and better product quality against relative small increases in scab control costs. As a result leaf removal is profitable for growers.

The **overall sustainability,** as estimated by DEXiPM-pome fruit, was not changed by the innovative applications performed. Although the biodiversity of the innovative IPM system was increased from low to medium because of both the reduction of the number of pesticides applications and the use of less impacting alternative treatments, the other environmental effects of the whole management were dominating the low effect of environmentally friendly scab control.

Other INNOVATIVE METHODS	On apple, substantial progress was made in bio-product development based on the biological control agent (BCA) *Cladosporium cladosporioides* H39 by WP 9 "Plant-pest-enemies interactions". Different formulations of this product from WP 9, task 2, were tested for field efficacy in commercial organic orchards in our WorkPackage 5. On-station testing resulted in interest from growers and companies to use this BCA in IPM apple production. Work with WP 1 "IPM design and assessment methodology" permitted the creation of a model called Premise, made for growers to test *ex ante* their protection strategy to control scab
LIMITS AND CONDITIONS OF SUCCESS, ADAPTATIONS	The innovative IPM system showed the potential of obtaining an effective and environmental friendly control of apple scab but with higher cost. Overall IPM 1 is the best for scab control and yield aspect with autumn leaf removal in order to reduce primary inoculums of the disease. The innovative tools tested showed that a further improvement of the environmental quality is possible, but with lower efficacy of disease control and at a higher cost. Although the environmental impacts were reduced, the innovative IPM system did not modify the overall sustainability of the complete orchard system, probably because the proposed IPM tools accounted for a little part of the entire system, so that their effect was not important enough to affect the entire system. Concerning the biocontrol agents, *Cladosporium cladosporioides* H39 was successful in organic orchard systems. Different formulations of the biocontrol agents and cost-effectiveness of the sanitation practices will be further studied.

GLOBAL REFERENCES	***Pure deliverables D5.1 and D5.2.*** **Alaphilippe A., Angevin F., Buurma J., Caffi T., Capowiez Y., Fortino G., Heijne B., Helsen H., Holb I., Mayus M., Rossi V., Simon S., Strassemeyer J. (2013) Application of DEXiPM® as a tool to co-design pome fruit systems towards sustainability IOBC Bull. 91:531-535**