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D5.3
IPM guidelines for pome fruit systems in Europe

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1. Summary

The 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.

To achieve this goal, on-farm and on-station experiments have been conducted on the main pests and pathogens in Europe. Innovative 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 this report, you will find information on the tested innovative control methods against pome fruit major pest and diseases: pear psylla and pear brown-spot, and for apple, on codling moth and scab. Conclusion on their overall sustainability with specific focus on environmental risk assessment and cost-benefit analysis are reported here. 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. Recommendations on the use of the various tested IPM tools and strategies are given.

2. Objectives of WP5

The general 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.

To achieve these goals, on-farm and on-station experiments have been conducted on the main pests and pathogens in Europe. Innovative IPM tools were tested under well-defined conditions in experimental orchards (see deliverables 5.1 & 5.2). Subsequently, they were tested in commercial orchards as part of a total IPM system, where drawbacks and bottlenecks become clear (internal documents 5.4 & 5.5).

In this report, you will find information on the tested innovative control methods against pear psylla and pear brown-spot, and for apple, on codling moth and scab.

3. Pear psylla control

3.1. Specific 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 with focus on pear psylla 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.

3.2. Tested strategies

Key elements of the approach to reach **the objectives for pear psylla control** were:

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:

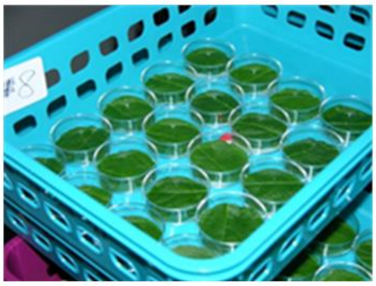
3. Test the sustainable pesticide spray schedule in practice;
4. Organise stakeholder meetings.

3.3. 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 (Fig. 1 & 2). 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

Figure 1.



Bean leaves with residue of pesticides for exposure of earwigs

Figure 2.

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.

Results showed that yield quantity was not affected by the selective pesticide schedule compared to the commonly used pesticide schedule which still contains pesticides with negative effects on predators. Growers did not 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.

3.4. Sustainability assessment

Compared to the standard system, the full season innovative IPM strategy substantially reduced both acute and chronic **environmental risks** as calculated by the assessment model SYNOPS-WEB (table 1). The risks were classified as follows:

Classes for the acute and chronic risk indices calculated with SYNOPS

risk classes of SYNOPS results	acute risk	chronic risk
very low risk	ETR<0.01	ETR<0.1
low risk	0.01<ETR<0.1	0.1<ETR<1
medium risk	0.1<ETR<1	1<ETR<10
high risk	ETR >1	ETR >10

Table 1. Synops-web assessment of the environmental risk of standard and IPM strategy for pear psylla control. Acute=short-time exposure and chronic = continuous or repeated exposure.

	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 the gross yield of the IPM system was lower than that of the standard system. Moreover, costs of IPM measures were slightly higher than in the standard system. As such, returns were € 2250/ha lower in the IPM system than in current practice.

3.5. Conclusion and recommendations

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.

4. Brown spot control (pear)

4.1. Context and specific 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.

4.2. Tested strategies

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.

4.3. Technical results

In on-research station experiments, different combinations of vinasse (= borlanda), *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 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 (Fig. 3 & 4). This result is relevant in order to reduce the inoculum of *S. vesicarium* during winter time.

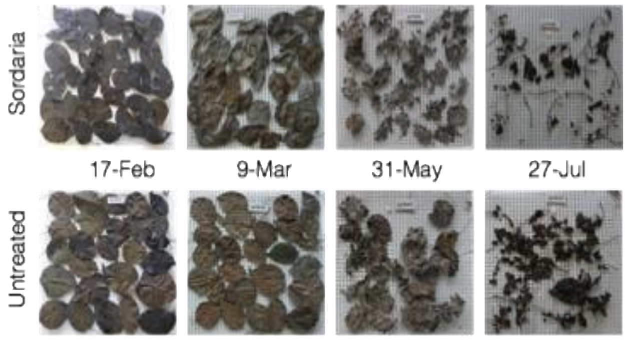


Figure 3. Comparison between degradation of the overwintering leaf litter in an untreated (Control) and in leaves treated with *Sordaria* sp.

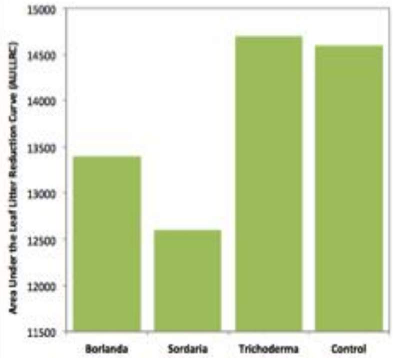


Figure 4. Amount of the leaf litter residues remaining at the end of the experiment (early August)

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 vinasse 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 IPM system and in the standard, but there was a 50% reduction in terms of pesticide usage.

4.3. Sustainability assessment

Over two seasons, the fungicide schedule for controlling brown spot on pear of the IPM 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 eco-toxicological profile of the pesticides used that showed a reduced impact on biodiversity of the orchard and permitted to enhance its environmental quality (Fig. 5).

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

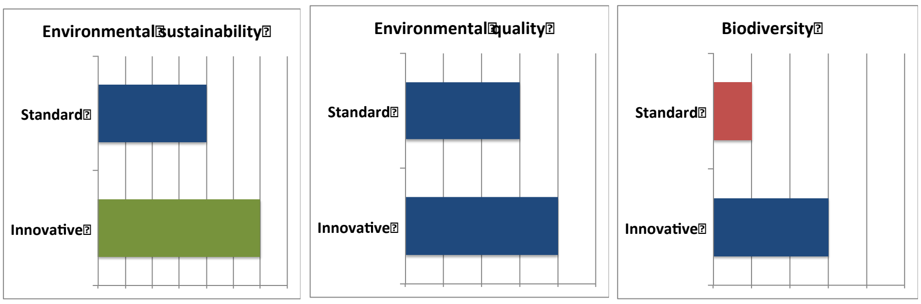


Figure 5. Sustainability assessment of Standard and Innovative brown spot management performed with DEXiPM over two seasons (2013-2014) in North-Italy

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). The innovative system gave 2% higher gross yields in case of low infection pressure (2014).

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

The IPM system increased the **overall sustainability** of the complete orchard system to “high” by comparison to the standard system.

4.4. Conclusion and recommendations

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 IPM approach are compensated in case of low disease level through a saving in fungicide applications and an increased top quality production.

5. Codling moth control (apple)

5.1. Context and specific objectives

Fruit trees require the application of 7-15 insecticides specifically targeting the codling moth (*Cydia pomonella*) in southern France. Exclusion netting, as a physical control tool, prevents this pest to reach the trees and potentially replaces all the treatments against this key-pest. There are two forms for this netting, either “a single-row” system (net covers each row) and the “whole-orchard” system (a modification of the anti-hail system).
The specific objective was to evaluate the integration of such innovative IPM tools into advanced fruit production strategies.

5.2. Tested strategies

Effects of whole orchards covered with single-row nets were studied under different management strategies in research station experiments on the orchard microclimate, the agronomic performances and the pest complex (fruit damage and infestation levels), including the rosy apple aphid (*Dysaphis plantaginea*). These 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.

5.3. Technical results

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). The mean number of rosy apple aphids was higher under the nets (Fig. 6) probably because some natural enemies (such as Cocinellidae) could not reach the aphid colonies. Conversely, codling moth and other Lepidoptera (e.g. fruit Tortricidae) were highly controlled and consequently the percentage of damaged fruit was close to zero (Fig. 7).

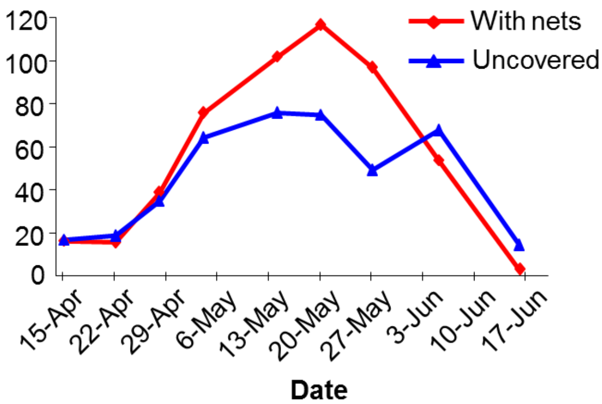


Figure 6. Mean rosy apple aphid number per shoot (total)

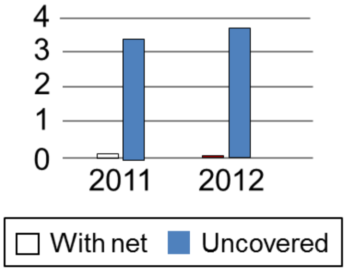


Figure 7. Percentage of damaged fruits by *C. pomonella* and *G. molesta* in 2011 & 2012

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 *versus* 14.8 with net).

5.4. Sustainability assessment

Our work revealed that the **overall sustainability** of orchards covered by exclusion netting was higher than non-covered orchards. This was due to (i) economic advantages of exclusion netting when hail damage risk is higher than 10% (the cost of netting included 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) (table 2).

Table 2. Synops-web assessment of the environmental risk: 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. For the meaning of the colours see paragraph 3.4.

	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*

5.5. Conclusion and recommendations

Seen from a pest control point of view, covering orchards with a 'single-row' version of netting, is efficient. 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.

6. Apple scab control

6.1. Context and specific 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%. 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.

6.2. Tested strategies

Small scale (**on-station**) and 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 with mating disruption using mainly granulosis viruses, Bt).

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.

6.3. Technical results

Results from the **on-station** experiment showed that scab leaf and fruit incidences were the highest in the most innovative systems of IPM2. Yield was the highest in standard and IPM1 systems. Fruit grading class I was the highest in IPM1 (Figure 8).

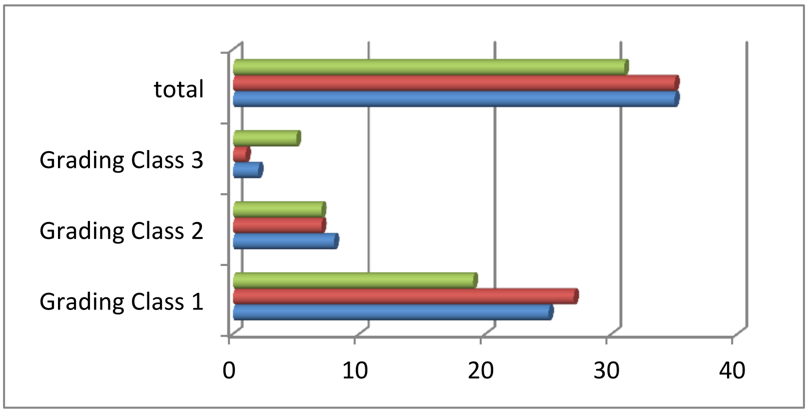


Figure 8. Fruits yield (t/ha) of on station experiment testing the standard growing system with two IPM systems; bars in blue: standard; in red: IPM1; in green: IPM 2.

Moreover, the on-station experiments showed that strongly reducing fungicides from the IPM1 schedule in the IPM2 system resulted in higher amounts of apple scab incidence (Figure 9).

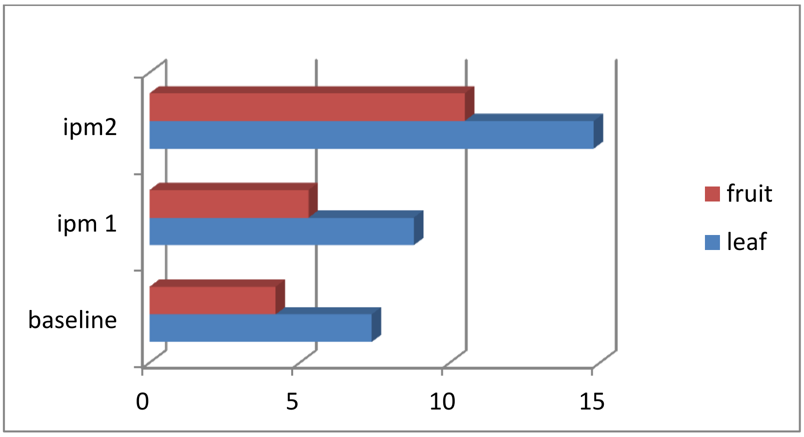


Figure 9. Scab incidence (%) in on station experiments comparing the standard growing system (baseline) with two IPM systems.

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 systems. Fruit grading class I apple was the highest in IPM1 and standard systems (21 t/ha out of the total of 31t/ha).

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

6.4. Sustainability assessment

The **environmental risk**, assessed with SYNOPS-WEB on aquatic organisms is mostly due to one specific active ingredient (dodine) in all three systems. The innovative systems allowed an improvement in both acute and chronic risk bees, and in chronic risk for aquatic organisms because of the reduced usage of this active ingredient (numbers in table 3).

Table 3. Synops-web assessment of the environmental risk: 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. For the meaning of the colours see paragraph 3.4

	Aquatic	Earthworm	Bee
Acute risk			
Standard	3.55	0.0025	0.0074
IPM 1	3,54	0.0044	0.0024
IPM2	3.56	0.0045	0.0023
Chronic risk			
Standard	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 (IPM1) 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 was increased from low in the standard system to medium in both innovative IPM systems 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.

6.5. Conclusion and recommendations

The IPM system showed the potential of obtaining an effective and environmentally friendly control of apple scab but with higher cost. Overall IPM1 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 IPM system did not modify the overall sustainability of the complete orchard system, probably because the proposed IPM tools account for a little part of the entire system, so that their effect was not important enough to affect the entire system.

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 on 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. The biocontrol agent *C. 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.

7. Other innovative tools tested

4.1 Spray equipment

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.

4.2. Tool development: Premise

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 and also to test the effect of the use of different IPM tools on the codling moth damage and consequent associated yield loss.

8. References

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.

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.

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.