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PURE: RESULTS AND LESSONS FROM THE 2011-2015 FP7 PROGRAM ON PESTICIDE USE AND RISK REDUCTION THE POME FRUIT EXPERIENCE

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ABSTRACT
The overall objective of PURE (Pesticide Use-and-Risk reduction in European farming systems with Integrated Pest Management) is to provide practical Integrated Pest Management (IPM) solutions to reduce dependence on pesticides in selected major farming systems in Europe. The project consisted of two main pillars: one developing knowledge and technologies, which were then tested in the second pillar, on the appropriate cropping system. We will illustrate here the approach and main outcomes of this four-year project, within the work package dedicated to pome fruit. Among the innovative IPM tools developed to control various pests, exclusion netting against the codling moth, was tested under well-defined conditions in experimental orchards. And subsequently, they were tested in commercial orchards as part of a total IPM system to identify drawbacks and bottlenecks. From this specific case study, a practical solution consisting of an IPM control method and toolbox for its implementation was delivered on a dedicated website, which will be presented.

Keywords: pesticide use, risk reduction, improvement loop, IPM tools.

RESUME
L'objectif global du programme PURE est de fournir des solutions pratiques de protection intégrée des cultures afin de réduire la dépendance aux pesticides dans les principaux systèmes de production en Europe. Le projet se composait de deux piliers: un sur des technologies en développement, qui ont ensuite été testés dans le second pilier, dans différents systèmes de culture. Nous allons illustrer ici cette approche et les principaux résultats de ce projet de quatre ans, dans un cadre général puis sur les fruits à pépins. Parmi les méthodes de protection innovantes développées pour contrôler divers ravageurs, l'utilisation des filets pour contrôler le carpocapse a été testée dans des conditions bien définies dans des vergers expérimentaux. Par la suite, les filets ont été testés dans des vergers commerciaux dans le cadre d'un système global de lutte intégrée pour identifier les inconvénients et les points clefs de leur utilisation. De cette étude de cas spécifique, une solution pratique consistant en une boîte à outils comprenant la description de méthodes de lutte accompagnée de conseils pour leur mise en œuvre a été fournie et est disponible sur le site du programme (www.pure-ipm.eu).

Mots clés : utilisation des pesticides, réduction des risques, boucle de progrès, boîte à outils PIC

BACKGROUND

Performance of current intensive agricultural systems relies on a heavy use and large-scale use of fossil energy, plant protection products and fertilisers. With the common use of these products, cropping systems have evolved to maximise production leading to agronomic practices that increase the risks of pest development (including arthropod pests, weeds and diseases) and in return to a strong dependence on pesticides.

To meet the worldwide demand of food security, agriculture has to increase the food production and its quality, but at the same time decrease the ecological footprint of the inputs. The challenge of Integrated Pest Management is to reduce pesticide-input together with an increased and reliable agricultural production in the future.

APPROACH OF THE EUROPEAN PROJECT PURE

The objective of PURE project was to provide IPM solutions and a practical toolbox for their implementation, in key European farming systems (annual arable and vegetable crops, perennial fruit crops and grapevine, and protected crops in greenhouses), in which reduction of pesticide use and better control of pests will have major environmental effects at the European scale. The project was designed in two main pillars, based on:

- cropping systems
- new knowledge and technologies (which feed the cropping system pillar)

To achieve this goal, an improvement loop was used over the years, where an IPM strategy is designed, tested using multifactorial experimentation under controlled condition and on-farm experiments, assessed, and redesigned, following these steps:

Step 1. State of the art: key pest identification and possible control methods

Step 2. Selection of interesting solutions to be tested on-station

Step 3. Based on on-station research results, interesting solutions to be tested in on-farm experimentation

Step 4. On-farm results, practical and economic feasibility, e.g. by cost-benefit analysis, and environmental and overall sustainability assessment → to provide a tool box of control methods with recommendations to facilitate their implementation.

From such approach, the most recent insights are incorporated in the studied cropping system. As key pests and diseases can be different among European regions, developed innovative IPM strategies will be different for each region. Concerning the cropping systems approach, experiments and farm testing compared three levels of management (conventional, intermediate and innovative/advanced IPM strategies) and their applications in different parts of Europe. Intermediate IPM was characterised by focusing on each pest individually using a mix of preventive and control methods to optimise control and minimise environmental and human health risks, with the aim of a significant reduction in pesticide use and preference to selective pesticides in case pesticides are still required. Advanced IPM considered the interactions between pest categories and gave also preference to non-chemical methods, even if these methods are not as effective as pesticides (see table below).

Cropping systems	Intermediate	Innovative	European regions
Wheat based rotations	More diverse crop rotation Extended use of existing warning and forecasting systems, crop-pest models	More diversified crop rotation than intermediate IPM also including cover/mulch crops; warning and forecasting methods	Northern Germany and Poland Northern France Scotland and Denmark

	Mechanical weed control methods	Non-chemical control methods	
Maize based rotations	More diversified rotations Cultural practices like sowing date and false seed bed preparation, crop cultivars choice Use of warning and forecast systems and DSS (Decision Support System), herbicide band applications coupled with mechanical weeding, use of *Trichogramma* sp.	More complex rotations, which include cover crops between two main crops, innovations in mechanical weeding, DSS, and innovative biological tools	Southern France and Northern Italy Hungary and Slovenia Southern Germany and Netherlands
Field vegetables (cabbages)	Non-intelligent and intelligent mechanical weed control techniques, including innovative devices biocontrol against root fly Supervised control of caterpillars and aphids according to control thresholds		UK, Denmark, France, The Netherlands, Germany, and Slovenia
Pomefruits (apple and pear)	Decision Support System to control pear brown spot (*Stemphylium vesicarium*) in combination with biocontrol agents and other sanitation practices Combination of cultural and control methods to control apple scab, and in particular the use of biocontrol agents Habitat manipulation to control rosy apple aphid and codling moth (among which exclusion devices) on apple, Assemble a full season pesticide spray schedule to control pear psylla without negative side-effects Test of precise sensing spayer.		Rhone Valley (France), the Netherlands, Lake Constance (Germany), Emilia Romagna (Italy) and Hungary
Grapevine	Biocontrol agents against powdery mildew, grey mould and grape berry moths Decision Support System to control foliar diseases Mildew resistant grape varieties Combination of Cultural Methods to Control grey mould Total green-cover as an alternative to herbicides / tillage		Atlantic, Continental North of the Alps, Continental-like South of the Alps, Mediterranean
Greenhouse (tomatoes)	Biocontrol agents and push-pull strategies against main pests Microbial pesticides against grey mould and soil-borne pathogens New greenhouse technologies (climate, irrigation and fertilization management) and new IPM technologies (monitoring and physical methods)		Mediterranean (Spain, France, Italy) The Netherlands

Table 1 Intermediate and innovative methods tested in Pure in the six studied cropping systems in different European regions

Tableau 1: Méthodes innovantes testée dans le programme Pure dans les six systèmes de culture étudiés dans différentes régions européennes

Harmonised methods were used, to ex-ante evaluate novel IPM tools and strategies and to ex-post assess improved promising IPM tools and strategies. Ex-post assessments were conducted with emphasis on (i) expected benefits in terms of health risks for workers and environmental aspects due to a reduced dependency on pesticide use on the one hand side and (ii) on possible economic and institutional hindrances to implement promising IPM tools and strategies in practice on the other hand.

Concerning new knowledge, five main objectives were developed:

- To provide tools and concepts for using various IPM methods to counteract the emergence of super strains of diseases, weeds and pests, and mitigate the negative consequences thereof.
- To identify factors that disrupt pest infestation and disease infection and provide the basis for novel crop protection methods
    - with potential of selected combinations of defence- and priming-inducing agents to enhance the effectiveness of natural defence (tested on wheat and tomato)
    - with biocontrol strategies and natural products that could function as biopesticides
- To explore the ecological processes that underpin the response of pests to changes in habitat and design ecological engineering strategies based on the management of habitat to achieve pest suppression.
- To develop new technologies for crop protection based on the combination of detection and monitoring methods at the macro scale (whole field) and micro scale level (a given location in the field) with decision tools and innovative crop protection solutions.
- To develop a generic approach for co-innovation of IPM technology and methods by farmers, advisors, local policy makers and scientists, which includes process monitoring capabilities, progress indicators and stakeholder interaction.

As we are writing this communication, the results are not fully exploited. All this information will be available on the PURE website (www.pure-ipm.eu) and some key results will be provided during the conference.

CASE STUDY: THE POME FRUIT GROUP

Pome fruits have a history in development and use of non-chemical IPM tools. Cornerstones of present IPM strategies in Europe include the biological control of spider mites (*Panonychus ulmi*), pear psylla (*Cacopsylla* spp.), woolly aphids (*Eriosoma lanigerum*) thanks to various predators and parasitoids, mating disruption of Lepidopteran pests, resistant cultivars and warnings systems against several pests and diseases such as apple scab (*Venturia* spp.). None-the-less, the number of pesticide applications on pome fruits is still high, with Treatment Frequency Index (TFI) values above 35 in certain years and region.

Within the EU-funded project Endure, hindrances in further applications of integrated fruit production were analysed. The main reasons why new IPM tools are relatively little used in practice were, among others, higher labour costs, higher yield risks, lower efficacy compared to pesticide applications, and in some cases lack of durability (i.e. resistance to microbiological insecticides or scab virulence on *Vf* gene-resistant cultivars). Moreover, the high specificity of most current IPM tools favours the development of secondary pests, which requires the use of additional treatments minimizing the benefit of IPM. Therefore, the goal of this Work Package is to overcome these hindrances for fruit crops and develop new innovative IPM strategies ready to be used in practice.

The PURE pome fruit group implemented a system and multi-pest approach, initially focusing on the key pests and diseases of pome fruits, and aiming to integrate the most promising innovative IPM tools into advanced fruit production strategies. Among these keypests, one of the most important is the codling moth with 7-15 sprays a year in average in South- Eastern France apple orchards (Sauphanor *et al*., 2009), and is a serious pomefruit pest in Europe. Among the available tools, a non-copyrighted method named ‘Alt’Carpo nets’ to cover the entire tree canopy with small-mesh nets and protect fruits against codling moth was designed in 2005 by the French extension services (Severac and Romet, 2008).

MATÉRIAL AND METHOD

We worked together with the extension services to evaluate the efficiency and the sustainability of this new practice: INRA carried out experiments with exclusion netting in order to assess the effects of nets on the orchard microclimate, the agronomic performances and the pest complex (fruit damage and infestation levels), including that of rosy apple aphid (*Dysaphis plantaginea*), under different management strategies. Extension services conducted on-farm experiments in the ‘Alt’Carpo’ network composed of 17 netted and 13 uncovered commercial apple orchards under IPM and organic management to evaluate the efficacy and feasibility, including labour, cost, etc., of such innovative IPM tools into advanced fruit production strategies.

RÉSULTS

The use of nets permitted a significant decrease in insecticide use in orchards under both organic and IPM management (Fig 1a).

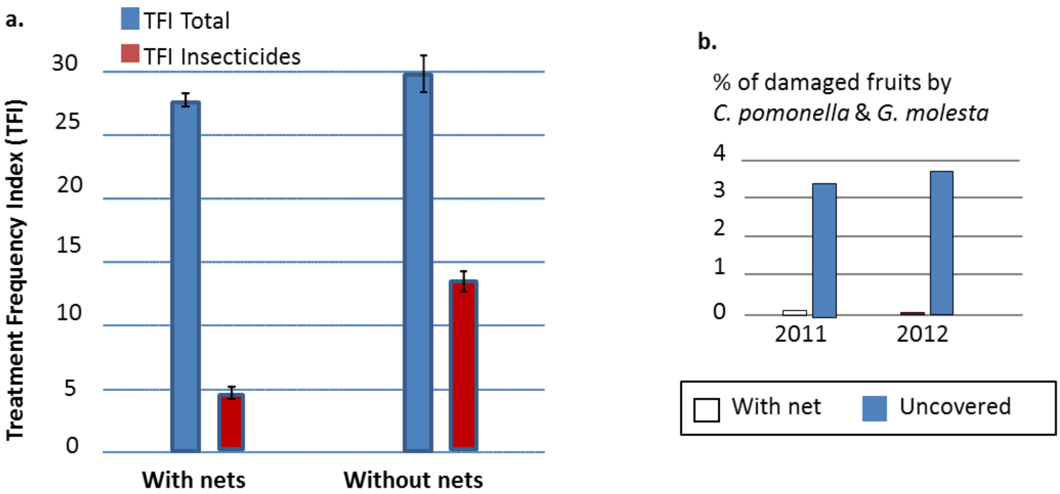

Figure 1a: Effect of nets on the treatment frequency index and Figure 1b: on the percentage of fruit damages in the Alt’Carpo network of commercial orchards.
Figure 1a: Effet des filets Alt’carpo sur l’IFT (Indice de fréquence de traitement/ 1b: sur le % de fruits atteints dans le réseau de vergers tests Alt’Carpo

In the 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.

However, nets modified the agronomic context of orchards, including microclimate and biological aspects. Climate under the net was little but significantly modified with an average increase in temperature (+0.7°C) and a decrease of 10% in the Photosynthesis Active Radiation. This could explain a delay of a few days (less than 5 days) for the harvest date of covered apple trees compared to control, without any effect on harvest quantity or fruit quality.

Moreover, as nets provide a high control of codling moth, most insecticides applied in orchards are therefore suppressed in netted orchards (Sauphanor *et al*., 2012) with possible effects on the pest complex. In our study, netting did not favour the development of other pests and diseases, with the exception of the rosy apple aphids (Marliac *et al*., 2013) and woolly apple aphids as well as *Grapholita molesta* and *Adoxophyes orana* in some orchards. Netting also protected fruits from sunburn, wind and hail, as well as from birds.

CONCLUSION

Netting represents an efficient way to control codling moth and enables a significant reduction in pesticide use without any major risks for the production. However, we recommend using the 'single-row' version of netting, as it is, up to now, more efficient and more durable than the 'whole-orchard' version (Alaphilippe *et al.,* 2013).

Due to the cost and constraints of netting (i.e. the devices and labour to open and close it for manual cultural practices), 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. In this case, the cost-benefit analysis showed that the cost of the nets was counterbalanced by the fact that nets limited risks of major yield loss, acting as anti-hail nets. Further improvements of the method to reduce the handling time of nets (including at hand-thinning and harvest) and therefore to reduce the costs are in progress.

Since nets did not favour the development of other pest and disease, we now look at the combination of the exclusion netting with other findings on various IPM tools to decrease both insecticide and fungicide use. Indeed, in our Work Package, the Hungarian team worked on the disease apple scab caused by the fungus *Venturia inaequalis*. We discussed about the possibility and feasibility to integrate within an orchard covered by nets their IPM strategy to control apple scab, including sanitation practices such as leaf litter removal and the use of biocontrol agent to reduce the sporulation of the pathogen (Köhl *et al.*, 2015). Such combining of various IPM tools and methods is a promising step towards more environmentally-friendly strategies in pome fruit orchards.

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