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European project "Pesticide Use-and-risk Reduction in European farming systems with Integrated Pest Management" – PURE

in collaboration with:

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Polskie Towarzystwo Ochrony Roślin

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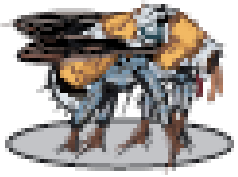

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Perennial crops

ADVANCED SOLUTIONS TO REDUCE PESTICIDE USE ON GRAPE

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Several IPM solutions can be adopted to reduce chemical pesticides on grape and a few alternative tools are available on the market or under development to control pest and pathogens on grapevine. In this review the existing solutions and the most promising technologies for the future are presented and discussed. An outlook on the priorities for the medium-long term is also discussed.

INNOVATIVE IPM TOOLS FOR MANAGING MAJOR DISEASES ON GRAPEVINE

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Downy and powdery mildews represent a major threat for all grape-growers worldwide. In particular, in areas characterized by temperate climate with abundant rainfall in spring and warm-dry conditions in summer, as most of the grape growing areas in Europe, it is necessary a constant application of fungicides in order to avoid severe yield losses. These factors lead to a spray scheduling almost calendar-based that is on average of 14-18 treatments per year.

During the EU-FP7 funded project PURE (http://www.pure-ipm.eu) the application of a Decision Support System (DSS) named vite.net® aimed to rationalize the application of fungicides was tested under farming conditions in different grape growing areas in the North and Central Italy. Moreover, the application of a bio-control agent (BCA) based on *Ampelomyces* spp. was also tested by on farm experiments in order to reduce the overwintering inoculum of *Erysiphe necator*, the causal agent of powdery mildew.

The adoption of the DSS over the 3-year period allowed the farms involved into the project to receive more information about the diseases development and the efficacy of the protection provided by the last fungicide sprayed allowing a reduction of 20% in the number of treatments that increased to a saving of 30% considering the Treatment Frequency Index over a 3-year period.

The use of *Ampelomyces* against powdery mildew overwintering inoculum tested during the project confirmed the potential of this BCA for sanitation treatments enabling to reduce the disease primary inoculum in highly powdery mildew affected vineyards and delaying the trigger of the powdery mildew epidemic in the following season. These results were particularly appreciable in those areas where the application of the BCA were possible at the yellow maturation stage of the chasmothecia.

The availability of these innovative techniques allowed a more flexible disease management strategies with the achieved goal of health bunches at harvest, the same yield as the standard IPM practices and a more sustainable use of pesticides.

ALTERNATIVES TO CONVENTIONAL INSECTICIDES TO CONTROL BERRY MOTHS AND MEALYBUGS IN VINEYARDS

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According to the Directive 2009/128/EC synthetic pesticides should be gradually replaced by non-chemical measures and IPM implemented. Organophosphates and pyrethroids are still used in European vineyards despite their unfavorable ecotoxicological profile. At the same time, knowledge on the effects on non-target organisms of modern insecticides (e.g., IGRs, neonicotinoids, inhibitors of acetyl-CoA carboxylase) is limited. Alternatives to conventional pesticides in controlling some important pests of grapes (e.g. berry moths and mealybugs) were evaluated in Italy. A number of microbial and botanical insecticides (i.e. *Bacillus thuringiensis*, azadirachtin, *Beauveria bassiana*, pyrethrins and spinosad) were tested against the European grapevine moth *Lobesia botrana*. Trials were carried out against the second larval generation in two vineyards located in Tuscany and Veneto regions, from 2011 to 2013. In another trial the impact of two predators (*Cryptolaemus montrouzieri* and *Nephus includens*) on *Planococcus ficus* populations was assessed in an experimental vineyard. A completely randomized design was adopted to compare experimental treatments with an untreated control, sometimes with a reference synthetic insecticide.

Regarding the control of *L. botrana*, trials stressed the high performance of spinosad whereas *B. thuringiensis* gave satisfactory results in Veneto only. The remaining insecticides were less effective. Side-effects of natural insecticides were evaluated. Leafhoppers (mainly *Empoasca vitis* and *Zygina rhamni*) were commonly recorded in the vineyard located in Veneto. They were sometimes more abundant in spinosad and pyrethrins treated plots. On the other hand, spinosad and pyrethrins reduced significantly predatory mite populations compared to other treatments. Regarding the control of *P. ficus*, the release of *C. montrouzieri* gave the best results. The effect of coccinellid releases was significantly higher than that of synthetic pesticides (spirotetramat). Implications for IPM are suggested.

LOW-INPUT CROP PROTECTION STRATEGY FOR APPLES POSSIBILITIES AND LIMITS

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In several European countries, consumers and retailers are demanding a large reduction or elimination of pesticide residues on fruits in order to minimize the environmental impact and the risk for human health. To achieve these goals, the producers need information and advice on designing sustainable production systems that reduce the use and the residues of pesticides.

In a four year trial with Golden Delicious and the scab resistant varieties Topaz, Otava and Ariane, a low-residue strategy (reduced use of synthetic fungicides) was compared with established crop protection strategies (integrated and organic apple production). In all strategies, alternative measures such as insect exclusion netting, mating disruption against codling moth (*Cydia pomonella*) and mulching of leaves to reduce scab (*Venturia inaequalis*) inoculum were applied.

Using the low-residue strategy, no pesticide residues could be detected and control of apple scab and powdery mildew was comparable to the integrated strategy and superior to the organic strategy. Losses due to bull's eye rot (*Gloeosporium album* and *G. malicorticis*) remained a weakness of the organic and the low-residue strategy for Golden Delicious and Topaz. However, hot water treatments after harvest reduced the incidence of this disease.

INTEGRATED PEST MANAGEMENT IN SWEDISH APPLE ORCHARDS

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We report here about field studies carried out in apple orchards with the aim to develop IPM strategies in co-operation with growers, advisors and pheromone companies. Our first step focussed on damaging moth species. Phenological and climatic data were collected during three seasons with the aim to set-up a forecasting system to predict the phenological development of six species of tortricid pests. The temperature regime during the winter was significantly correlated with the population density in the following spring. A web-application of these data is under development in co-operation with a growers´ co-operative with the aim to support the optimization of insecticide use. In connection to this, a new multispecies mating disruption device for the control of a wide number of tortricid pests was specifically formulated by a company and tested in Swedish orchards. Pheromone treated plots were monitored throughout the season by trap catches and visual inspections and growers were promptly alerted when larval entries and thus control measures became necessary. During a three years experiment, the new pheromone formulation showed a comparable or higher efficacy than the standard chemical treatment in the control of the tortricid species. Some of the growers involved in the project expressed their interest to use this device as soon as it will be registered in the country. We also studied the attack pattern over the orchard of the apple fruit moth, which moves from the forest to the apple orchard inflicting serious damage in certain years. Through the use of a kairomone trap, we could localize the spots under attack and accordingly minimize the use of insecticides only to a restricted part of the orchard. Some of the growers participated actively in this monitoring activity and learned how to use the monitoring traps, how to recognize the pest and how to apply the associated economic threshold. As a second phase we monitored the activity of a range of natural enemies, including predatory heteropterans, earwigs and lacewings, during the entire season. The presence and biocontrol effect of the named beneficial organisms was enhanced by a low level of insecticidal disturbance. As a participatory activity, growers were trained to both distinguish natural enemies at different stages and how to preserve them in the orchard. In order to further attempt an enhancement of biocontrol along with a decrease in insecticide use, we will involve growers in the set-up and evaluation of conservation biological control practices to increase the activity of those natural enemies associated with the biocontrol of aphids, scales and tortricids.

BIOLOGICAL CONTROL OF APPLE SCAB (*VENTURIA INAEQUALIS*) BY *CLADOSPORIUM*

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Apple scab caused by *Venturia inaequalis* is the most important disease in apple production. Control of apple scab currently depends on the multiple applications of fungicides. The potential of the antagonistic isolate *Cladosporium cladosporioides* H39, originating from a sporulating colony of *V. inaequalis*, to control apple scab was tested in eight trials during two years in orchards in Eperjeske (Hungary), Dabrowice (Poland) and Bavendorf (Germany) planted with different varieties. The overall results of the field trials consistently showed for the first time that stand alone applications of the antagonist can control apple scab in leaves and fruits. Efficacies of calendar sprays reached 42 to 98% on incidence of leaf scab and 41 to 94% on fruit scab. The antagonist also was effective if applied one or even several days after infection events. This has been found in several field trials and has been confirmed by a trial with single spray applications at different intervals before or after infection events.

The effects of fungicides, insecticides and chemical thinners commonly used in integrated or organic apple production have been evaluated. A strain-specific quantitative TaqMan-PCR has been developed and used in studies on the population dynamics of *C. cladosporioides* H39 in the orchard. This knowledge is essential for the further development of IPM systems with the integrated use of the antagonist.

SUSTAINABILITY EVALUATION OF AN INNOVATIVE APPROACH FOR MANAGING BROWN SPOT DISEASE ON PEARS IN ITALY

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The largest Italian pear growing area, about 65% of the national production, is located in Emilia-Romagna region, along the Po Valley. The climatic conditions of this area are often favourable for diseases development and, in particular, brown spot of pear caused by the fungus *Stemphylium vesicarium* represents a major threat for growers and requests regular fungicide applications for a proper control. This usually leads to a regular interval (i.e. calendar based) chemical sprays, for an average of 15–25 times per year, to keep the level of disease incidence on fruits under 1–2% and avoid significant yield losses due to the impossibility to sell the pears as "premium quality".

During the EU-FP7 funded project PURE (http://www.pure-ipm.eu) an innovative approach aimed to reduce the primary inoculum of *S. vesicarium* was developed on experimental sites and then tested under farming conditions in order to increase the sustainability of integrated pest management strategies usually applied in the area.

Under experimental controlled conditions different biocontrol agents (BCAs) were tested in order to assess their ability for leaf litter degradation and thus their direct effect on diminishing the amount of overwintering inoculum of the causal agent of brown spot. Under farming conditions the use of a Decision Support System (DSS) for scheduling fungicide applications was combined with the periodical applications of a BCA against the primary inoculum *S. vesicarium*. This innovative IPM approach limited the amount of chemical compounds used in the orchard by about 30% on average, under tested conditions, and tends to increase of the farmers return for covering other costs.

RAIN COVERS, AN INNOVATION STUDIED IN APPLE ORCHARDS TO PROTECT AGAINST APPLE SCAB

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While reducing the use of plant protection products and the risk of residues on fruits, new production systems should offer the same profitability and quality as current orchards. In this context, the mission of the French national technical Institute for fruit and vegetables (Ctifl) is to study an array of innovative techniques, and test very forward-looking features, such as installing rain covers in Apple orchards. The trials conducted by Ctifl in its experimental orchards in southwest France since 2010 are designed to assess the protection rain covers offer against apple scab, and analyse the overall impact on production, yield management and fruit quality. The main goal is to create a mechanical barrier against rain.

The experiment is carried out on three varieties: Braeburn Mariri Red$_{cov}$, Gala Brookfield® Baigent$_{cov}$ (planted in 2005) and Pink Lady® Rosy Glow$_{cov}$ (planted in 2014). Three different types of rain covers are tested. The first one consists of two plastic covers fixed above the trees, but placed under the hail nets (figure 1). The second one combines plastic covers and hail nets in one and the same system (figure 2). The last one is composed of five plastic strips sewn partly on a hail net so as to move with the wind and be less wind-resistant (figure 3).

The following topics are studied: Biological efficiency against apple scab, but also “Gloeosporium” rot (*Neofabraea alba*); Secondary effects against Powdery Mildew, flyspeck and sooty blotch, woolly aphids and green aphids; Incidence on yield and fruit quality. Pollination and flowering potential; Microclimate under rain cover;

Irrigation and fertiliser management; System approach; Costs.

The apple scab results over four seasons (2010–2014) are encouraging, especially in 2013 with a high apple scab pressure. Without any fungicides sprayed during the whole season, the apple scab level on shoots was maximum 3% and less than 1% on fruits. However, other fungi may appear, such as flyspeck symptoms and sooty blotch in summer 2013 or an important (62%) powdery mildew infestation in 2014.

Rain protection changes the way to produce apples and has to be considered as a new integrated production system. Special attention must be given to irrigation management, the impact on flowering potential and the shading effect on fruit colour.

SEASONAL DYNAMICS OF INSECT PESTS AND THEIR PREDATORS IN CITRUS ORCHARDS OF DISTRICT SARGODHA, PAKISTAN

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Citrus leaf miner, citrus whitefly and citrus psylla are the major insect pests of citrus orchards in district Sargodha. Spiders being natural predators may be helpful to keep the insect pest populations below economic enjoy level. Present study was designed to estimate biodiversity and guild structure of spiders in the citrus orchards of Sargodha. Seasonal dynamics of citrus insect pests and predator-pest (spider-pest) relationships was also studied. In total, 2665 spiders belonging to 12 families, 23 genera and 43 species were captured. Highest abundance of spiders was recorded during the month of March, 2014 whereas, least abundant trapping session was January, 2014. Species and family composition of spiders varied on foliage and ground. Abundance of spiders among sites differed significantly. However, non-significant difference was observed in the richness, diversity and evenness among study sites. Abundance and infestation of pest was found to be synchronized with the abundance of spiders in various trapping sessions. Maximum infestation of citrus leaf miner, citrus whitefly and citrus psylla was recorded in March, 2014 supporting maximum spider abundance in this month. Correlation between abundance of pest and predators suggested that spiders can effectively control pest populations in the field. This finding is important regarding spiders as potential bio-control agents.

RESPONSE OF PEST AND PEST-ENEMY POPULATIONS TO LANDSCAPE CHARACTERISTICS IN ORCHARD SYSTEMS

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Managing the spatial distribution of crop and non-crop habitats over landscapes could be used as a means to reduce insect pest densities either by directly affecting pest populations or by providing resources that enhance pest enemy populations. Increasing quantity of semi-natural habitats over landscapes is indeed generally related to higher abundance of pest enemy populations but this does not always translate to lower pest abundances in fields. Further, because perennial crops are more stable than annual crops, it has been suggested that arthropod species in orchards may be less affected by landscape characteristics than those present in annual crops. Our objective was to assess if and how the abundance of diapausing codling moth (*Cydia pomonella*) larvae and their parasitoids respond to agronomic and landscape factors in an approximately 80 km2 pome fruit production area of south-eastern France. In this area, apples are mainly grown in conventional orchards with approximately 5% organic orchards. We sampled diapausing *C. pomonella* larvae in approximately 50 apple orchards during five consecutive years (2006–2010) and characterized the landscapes surrounding the orchards in 250 m wide surrounding areas. All orchards, hedgerows and other landscape characteristics of the study area were manually digitalized with ArcView (Version 9.1, ESRI) from aerial photographs (BD ORTHO, IGN, 2004-pixel size: 0.5 m) and maps were updated by yearly field surveys. Farmers were also surveyed yearly to collect information on crop management in sampled orchards. Landscapes surrounding orchards were characterized by the proportions of organic, conventional and abandoned orchards, of woodland, of urban areas and by the length of irrigation ditches. The hedgerow network was characterized by its total length and its overall windbreak effect towards dominant northern winds.

Results indicated a major effect of crop management both at local and landscape scale. A previous study had shown that codling moth larvae are more numerous in organic orchards and that, although the codling moth is specialized on orchards, the number of codling moths is lower in orchards within an area with high orchard density. There was some indication that this last effect was mostly due to the insecticide treatments in surrounding orchards. Codling moth larvae were also less abundant in landscapes with more windbreak hedgerows. Parasitism rates were globally low each year (<4.5% in average). Parasitism was higher in organic orchards as compared to conventional and it decreased with increasing proportion of conventional orchards in the landscape. Overall our results thus indicate that management of pest and pest-enemy populations should be considered over areas that are larger than that of the orchard (areas of approx.20 ha were considered here). They also indicate that possible positive effects of semi-natural habitats on pest control may be masked in intensive landscapes.

ROLE OF SPRAY APPLICATION IN IPM POME FRUIT CROPS

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In fruit crop spraying the aim is to achieve a uniform spray deposition all over the crop canopy structure. Losses to the soil underneath the crop and outside the orchard, through spray drift are to be minimised. It is known that sprayer settings are important for spray distribution in tree and crop canopy. Matching spray volume and direction to orchard tree sizes and shapes can reduce chemical application rate, thus reducing operational costs and environmental pollution. Manual or sensor actuated orchard sprayers have shown potential reductions in agrochemical use of 30% and more. Sensors quantifying crop parameters such as quantity of biomass and photosynthesis activity are commercially available. Sensors to evaluate the plant stress or spectral analysis of the crop canopy parameters open the potential for more target oriented spraying in crop protection. Spray systems treating individual plants based on fluorescence or canopy reflection information have been developed. Precise application techniques recently developed able to vary dose rates are obtained with switchable number of nozzles varying in flow rate respectively in a continuous and a stepwise way. Based on these possibilities we can achieve smaller units of treatment in the field. In spraying crop protection products this will lead from a full sprayer width or height treatment to section wise and even nozzle wise variable applications and fulfilling the needs of IPM.

An example in which the different elements of precision farming and IPM are combined in fruit growing were part of the EU projects PreciSpray, Endure, PURE and the Dutch Water Framework Directive Project Innovations Squared. An introduction is given to the last steps made in the development in the PURE project. An overview is presented of recent developments and introductions in agricultural practice of crop adapted spraying for crop protection in fruit crops. Special attention is paid to the development of Canopy Density Spraying (CDS) of a pear orchard; to show – under practical conditions – that crop adapted spraying is possible and has its advantages. The benefits for the environment are shown by means of reduced use of plant protection products (PPP) in order to maintain comparable spray distributions as with standard application techniques and maintain good biological efficacy.

To show where differences exist between a CDS-sprayer and a standard application technique spray deposition measurements were done in apple and pear orchards.

The CDS-sprayer used was a KWH cross-flow fan orchard sprayer equipped with a variable air support system (VLOS), a LIDAR laser scanner measuring the size and density of the pear tree canopy, and a variable dosing system based on Lechler VarioSelect nozzle bodies containing pneumatically switchable sets of two standard hollow cone nozzles and two spray drift reducing venturi hollow cone nozzles. The KWH-CDS sprayer can at three height levels in the tree adapt spray volume in four steps to the leaf development of the fruit crop.

EVALUATION OF SPRAY-DRIFT REDUCTION METHODS IN APPLE ORCHARDS WITH EFFICACY AND SIDE-EFFECTS ASSESSMENTS

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The codling moth *Cydia pomonella* L. is a key pest in Italian apple orchards. Several insecticide applications are made in northern Italy.

The spray-drift of pesticides may have a negative impact on the environment, including damage to non-target organisms, aquatic ecosystems. The drift of some insecticides can also produce detrimental effects to beneficial arthropods. In particular, predatory mites can be considered bioindicators for pesticide environmental risk assessment.

According to the UE Directive 2009/128/EC, the reduction of spray-drift is required to achieve the sustainable use of pesticides. In this framework the effectiveness in the control of *C. pomonella* and the side-effects on predatory mite populations of different drift-spray methods were evaluated.

Four field randomized block experiments were carried out in a typical apple growing area located in Verona district, from 2012 to 2014. Chlorpyrifos-ethyl (Dursban® 480 EC, 480 g ai/L EC) and chlorpyrifos-methyl (Reldan® 22, 225 g ai/L EC) were applied with different spray apparatus systems. Conventional nozzles (Albuz, ATR 80 yellow), low drift nozzles (Albuz, TVI 80015 green), and conventional nozzles with an adjuvant rapeseed oil (Codacide oil®, 864 g ai/L, DuPont) were compared. The efficacy of insecticides was evaluated considering the number of fruits damaged by *C. pomonella*. Predatory mite densities were assessed in the laboratory and the spray-drift reduction was measured by water-sensitive paper placed 4 and 8 m from the spray apparatus.

The use of low drift nozzles always reduced the spray-drift with significant differences at 4 m on 2013 in chlorpyrifos-methyl treatment; no differences in the efficacy and side-effects were found in all applications. There were no significant effect in terms of efficacy and side-effects on predatory mites numbers when comparing low drift and conventional nozzles.

The adding of adjuvant to conventional nozzles did not reduce the spray-drift nor the side-effects for both insecticides. Moreover, it didn't increase significantly the efficacy of conventional nozzles.The implications of the spray-drift reduction on IPM were discussed.

APPLE SAWFLY CONTROL – A PARTICIPATORY AND APPLIED APPROACH 24

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Apple sawfly (*Hoplocampa testudinea* Klug) is a serious pest in European organic apple production. In Swedish conventional orchards, sawflies and aphids are controlled simultaneously by applying the systemic neonicotinoid acetamiprid. Although the pest inflicts high injury in organic orchards, no approved and efficient control measures are currently available. A participatory approach was therefore chosen to conduct an applied research project where researchers, growers and advisors collaborated to develop a functional pest control strategy to be used in both IPM and organic orchards.

The apple sawflies hatch during a short period at the stage of petal fall in apple trees. To achieve efficient control and avoid non-target effects, the correct timing of control measures is crucial. Existing forecasting methods, based on temperature sums or tree phenology, differ by region and require validation and possibly adaptation before implementation. We optimized the timing of deploying white sticky traps for monitoring or mass-trapping in the field. The average emergence of sawflies occurred at 169 ± 20 degree-days counted from March 15 (threshold temperature 4°C). The difference in emergence from the existing first flight model of 177±10 degree-days was found to be acceptable. Accumulated oviposition of 85% at full bloom (BBCH 65) suggests that mass-trapping and monitoring could stop at this time. This is supported by a trend towards decreased trap catches during that period.

Results from this study contributed to a better understanding of the application timing of *Quassia amara* extracts against the apple sawfly at egg hatch. Three application times were compared: (A) at 50% petal fall (BBCH 67), (B) at a date calculated using female trap catch numbers and temperature sums, and (C) prior to peak egg hatch observed in the field. All treatments resulted in a significantly lower percentage of damaged apples compared to the unsprayed control, with the least damage (1.3%) in plots treated according to method (B). The phenological stage of 100% petal fall (BBCH 69) was simultaneous with the application time recommended by the temperature sum model. Hence, this stage may be used to time application of *Q. amara* extracts where growers have no access to temperature sums.

Results showed that models based on temperature sums may be used outside their previously known geographical limits. The participatory approach of this study along with the optimization of control measures has achieved a stronger national support for an approval of *Q. amara* within the EU and a progress towards national implementation of the forecasting method in advisory bodies.

DEXIPM GRAPEVINE, A MULTIPLE CRITERIA MODEL FOR SUSTAINABILITY ASSESSMENT OF GRAPEVINE CROP PROTECTION STRATEGIES

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Viticulture is characterized by a high use of pesticides compared to other crop industries (Gary et al., 2010), which generates concerns for human health and quality of the environment. Yet the use of pesticides, and other variables of economic importance such as yield, vary a lot among regions and farms within the same region (Meziere et al, 2009). A thorough analysis of the economic, social and environmental dimensions of sustainability is then needed to assess and compare existing cropping systems or prototypes of innovative ones.

To this end, DEXiPM, a qualitative multi-criteria assessment tool (Pelzer et al, 2013), was adapted to grapevine. A strong interaction with the first users (members of the FP7 Pure project from France, Germany and Italy) has brought to significant modifications, mainly on the economic and environmental branches. The working group has detailed some aspects of the grapevine management such as soil cover and choice of crop protection products.These changes have been validated by assessing some case studies.

A regards the *economic sustainability*, the *selling price* considers the expected yield (that may be linked to geographical indications), the certification of specific cultivation practices and the existence of marketing strategies. The specific case of biocontrol products is considered: they are included in the *production cost* but not in the environmental assessment.

In the *social sustainability* branch, few criteria have been modified, such as the *risk of contamination by mycotoxines* and the *risk of pesticide residues*.

The three components of the *environmental sustainability* have been adapted: *resource use*, *environmental quality* and *biodiversity*. A major change is that the period of cover cropping and percentage of soil covered have been introduced as they relate to a number of criteria: *water use*, *pesticide leaching*, *nitrate leaching*, *compaction risk*, *runoff risk* and *soil organic matter*. *Pesticide ecotoxicity* is assessed with the TFI of a list of highly toxic products. The *energy consumption* criterion has been adapted to include cultivation practices specific to viticulture. The *organic matter* is assessed in relation to specific *organic amendments* used in viticulture, *vine shoot management* and *soil cover*. At last biodiversity has been adapted for both the flora (by considering cover crops, flower strips and hedges) and fauna (by considering the *natural enemies in the phyllosphere and pollinators*.

As a result, the number of attributes of the DEXiPM model for viticulture has been reduced by 10% compared to the arable crop version.

The assessment of contrasted strategies of crop protection provides evidence that specific features of vineyard management have been captured in the new version of DEXiPM for grapevine.

PARTICIPATIVE DESIGN AND ASSESSMENT OF INNOVATIVE LOW-INPUT GRAPEVINE CROPPING SYSTEMS

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Since 2012, with the support of the PURE Project, three innovative experimental platforms were built in France to test low-input grapevine cropping systems (located in Angers, Bordeaux, and Montpellier).

The objectives were to reach a high reduction of pesticide use (over 50%) and to promote the alternative IPM and biocontrol methods without any decrease in yield and quality. Innovative cropping systems are needed in viticulture to achieve these goals. After a first step of prototyping of these new cropping systems, experimentations were carried out to assess the performances of the prototypes.

We make the hypothesis that innovation for pest and disease management in perennial crops comes from combination of practices and their interactions. Expert groups designed the prototypes. They built the set of objectives and constraints (SOC) to be satisfied by the prototypes. These grapevine cropping system prototypes were then assessed on the three platforms developed during the PURE project.

A DEXiPM Grapevine model was adapted in PURE project for the overall assessment of the sustainability of the tested farming systems.

The testing of cropping systems was radically different from classical factorial trials that test the effect of a modality in agronomy. To evaluate the system performance, experimental plots must be independent agro-ecosystems and be fairly large (over 2,000 m²). The homogeneity of the physical environment, soil and climate is important. With repetitions, these tests mobilize significant investments over several years in the case of perennial crops.

Cropping system trials experiment a set of decision rules designed for the management of crop practices. If the objectives of the SOC are not achieved, prototypes can be re-adjusted before validation and dissemination.

Three main ways of pesticide reduction are explored: (i) IPM, (ii) alternative products and biocontrol, (iii) zero-pesticide cropping systems based on new grapevine mildew resistant varieties. Seven prototypes are tested in INRA experimental farms in Angers (Loire Valley, center of France), Bordeaux (atlantic region), and Montpellier (Mediterranean region).

The first results in 2012 showed that 50% of the treatment frequency index (TFI) was obtained in over 40% of the tested prototypes.

This reduction in pesticide use results primarily from improved control strategies and control of the application of plant protection.

The first DEXiPM Grapevine assessments show the high environmental performance of innovative biocontrol strategies. However, the IMP strategies have the best overall sustainability for the moment with better economic and social assessment.

Pesticide efficiency and substitution allow the first steps of progress in the systemic approach carried out. The re-design of the grapevine system will be necessary in order to reduce pesticide use despite

BIENNIAL CROPPING – THE ANSWER TO IMPROVED IPM IN RASPBERRY? 31

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Raspberry is a labour-intensive crop. The common practice is to grow summer raspberry as a mixture of primocanes (this year's shoots) and floricanes (2-year old canes, bearing fruit this year) in the same row. However, the two cane types have different requirements regarding plant protection, pruning, trellising, fertigation, etc., and they compete for light as well as other resources. Moreover, growing the two cane types together promotes a build-up of pests and diseases because of the continuous presence of plants and the very short distance between old and new shoots.

In so-called biennial cropping, the two cane types are grown in separate rows, either in every second row or in different parts of the plantation. Rows are completely cut down after harvest. This cultivation system allows plant care to be optimized for each cane type, and new shoots do not hamper picking or removal of old shoots. Plant protection measures that are damaging to pollinators or lead to unwanted residues in the fruits can be reserved for primocanes. In addition, separating the two cane types disrupts the life cycle of many pests and diseases, delaying their spread to primocanes.

The downside with biennial cropping is of course that each row only gives a harvest every second year, theoretically meaning a 50% reduction of the yield per ha of raspberry. However, yield per metre of row is not halved in biennial cropping (in a UK trial it was even doubled). With the costs of labour increasing, and the selection of plant protection products decreasing, the advantages might more than compensate for the reduction in yield. Despite this, biennial cropping is not widely practiced in Europe. Difficulties in finding soil free of root rot (*Phytophtora rubi*) and high investments in polytunnels may contribute to a focus on maximizing yield per ha instead of minimizing costs per kg of yield.

In Norway, a handful of growers has converted to biennial cropping, keeping primocanes and floricanes in separate plots. We have started a four-year project aiming to compare biennial and ordinary cropping with regard to optimal cane density, need for plant protection measures, yield, and overall profit in 'Glen Ample'. We would like to hear about experiences with this growing technique from other countries. We will present the project and some potential effects of biennial cropping on raspberry pest and disease management in a Northern climate.

STUDY AND APPLICATION OF THE CODLING MOTH EXCLUSION NETTING METHOD IN ITALY AND FRANCE

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The regions Emilia-Romagna (Northern Italy) and Rhone valley (Southern France) are two important fruit orchard areas of Europe, where pome fruits have high economic relevance. These orchards require the application of many pesticides, including a high proportion of insecticides against codling moth (CM). In this context, the French extension services designed in 2005 an exclusion netting method named Alt'Carpo, whichcovers the entire tree canopy to protect fruits against CM. Alt'Carpo are white nets (mesh size 2.2 x 5.4 and/or 3 x 7.4) and can be either single-row or whole-orchard. Nowadays around 2000 ha are covered by the Alt'Carpo nets in France. Nets were introduced in Italy on pear in 2008 and now it is applied on 350 ha. Since 2009, the Italian and French Alt'Carpo networks have compared and shared their experiences on this topic. In both countries, a high level of efficacy of nets was observed against CM, especially for the 'single-row' system, with a significant decrease in insecticide use in orchards under organic and IPM management.

Netting reduced the development of other pests and diseases, with the exception in France, of the rosy and woolly apple aphids, *and leaf minors* and, in Italy, of *Metcalfa pruinosa* and Tingidae requiring the application of specific insecticides in some cases. Netting also protected fruits from sunburn, wind, hail, birds and, in Italy, from mirids.

Climate under the net was little but significantly modified with an average increase in temperature (+0.7°C) and a decrease in the Photosynthesis Active Radiation (–15%), and a decrease in relative humidity (–2.3 H.R.) in Italy. No significant modification of the tree architecture, neither of the fruit quality (only few days delay for the harvest date in France) and orchard yield was observed in the orchards with nets. In the Italian pear orchards, the vegetative growth was slightly decreased. Costs of net application are described and recommendations on its use will be given.

IMPACT OF SOIL AND CANOPY MANAGEMENT PRACTICES ON PESTICIDE USE IN VITICULTURE IN FRENCH REGIONS

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To face the negative impacts of pesticides on human health and biodiversity, France adopted in 2008 an action plan aiming at decreasing pesticide use by 50% within 10 years. This is a major challenge, particularly for viticulture, which consumes a very large quantity of pesticides, as vineyard is very sensitive to pests and diseases. Different methods (eg IPM) have been proposed for a more integrated production. Among them, prophylactic practices such as fertilization management, soil surface management and pruning management (shoot thinning, de-budding, leaf thinning, green harvesting,..), aim at regulating production (especially for wine quality), but also contribute to limit pests and diseases development. Thus these practices can be considered as levers for reducing pesticide use. We used a statistical analysis to explore the relationships between the use of these practices and the level of pesticide use. The analysis was based on two surveys carried out by the French Ministry of Agriculture on the cropping practices in vineyards in 2006 (5217 fields) and 2010 (6007 fields) throughout the country. Several indicators were used to evaluate the correlations between these *a priori* prophylactic practices and the intensity of pesticides use. Indicators on the use of pesticides (Treatment Frequency Index) and fertilizers were calculated, and indicators on canopy and soil surface management, were designed based on variables available in the database. The analysis was conducted for ten regions (NUTS2) and for the two available years, which corresponded to medium vintages in terms of climate and pest pressure. Results showed that the nature and the number of assumed prophylactic practices varied between and within regions. We found a significant reduction of herbicide use between 2006 and 2010 at the national scale, which was not observed for all regions. At the regional scale, this decrease was correlated with a change in the type and proportion of soil management practices (chemical weeding, permanent grass cover, tillage…). However, combinations of other practices commonly used to reduce vine vegetative vigour (reduced fertilization, green pruning) did not lead to a reduction of pesticide use at the regional scale. These relationships should be further studied, as some information were missing in the survey, such as biophysical field characteristics (soil type, vine vegetative vigour …) or farmers' protection strategies. To this end, individual surveys will be performed to explore in detail these relationships.