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PURE

Pesticide Use-and-risk Reduction in European farming systems with Integrated Pest Management

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Collaborative Project
SEVENTH FRAMEWORK PROGRAMME

D6.2
IPM guidelines for grapevine in Europe

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Dissemination Level	
PU Public	**PU**
PP Restricted to other programme participants (including the Commission Services)	
RE Restricted to a group specified by the consortium (including the Commission Services)	
CO Confidential, only for members of the consortium (including the Commission Services)	

Table of Content

1. Objectives

The objective of the deliverable is to provide guidelines for IPM solutions on grapevine based on the results and experience of the PURE project. The results have been analysed and summarised and will be used as booklet for disseminating the information among stakeholders

2. Deliverable procedure

GRAPEVINE
« Results and lessons learnt from PURE »

FEBRUARY 2015

OBJECTIVES

The aim of Work Package 6 was to develop innovative integrated pest management (IPM) methods for grapevine and to stimulate the uptake of these methods into practice. More specifically, the objectives were:

1. To produce IPM solutions that address the most critical pest problems in European grapevine systems
2. To test candidate IPM solutions in on-station and on-farm experiments
3. To assess and compare field-tested candidate IPM solutions using multiple criteria and endorse viable solutions for mainstream dissemination
4. To stimulate and promote uptake of innovative IPM methods into practice.

APPROACH (EXPERIMENTS, ASSESSMENT TOOLS, …)

An initial survey identified the most important pests and diseases of grapevine in terms of pesticide input and risk of losses in the different regions of Europe. A database on the possible IPM solutions based on the existing literature was built. On-farm and on-station experiments were carried out on the identified main pests and pathogens.

In this report, you will find information on the tested innovative control methods and IPM solutions against *Botrytis cinerea* (grey mould), *Erysiphe necator* (powdery mildew), *Plasmopara viticola* (downy mildew), *Lobesia botrana* (European Grapevine Moth) and Planococcus.

Tested IPM solutions and innovative control methods are based on decision support systems (DSSs), combination of microbial biocontrol agents (biopesticides), reduction of the overwintering inoculum of the diseases, agronomic practices and resistant varieties.

PESTS

Botrytis cinerea (grey mould)

Erysiphe necator (powdery mildew)

Plasmopara viticola (downy mildew)

Lobesia botrana (European Grapevine Moth)

INNOVATIVE METHODS

Intense interaction between WP 9 “Plant-pest-enemies interactions”, WP 11 “Emerging Technologies” and WP 6 “Innovative IPM on grapevine” took place

	during the PURE project especially for the innovation related to microbial biocontrol agents (BCA) and vibrational mating disruption. Thanks to the interaction with advisors, farmers and industries, commercial products and prototypes have been tested and critically evaluated.
LIMITS AND CONDITIONS OF SUCCESS, ADAPTATIONS	Several solutions have been tested and validated in the experimental stations and then assessed under real commercial conditions in farms as DSSs, agronomic measures and registered biopesticides. However especially for the experimental microbial biocontrol agents, it was not always possible to validate them by growers in all the participating countries because without registration (Reg. 1107/2009) they cannot be applied in commercial farms. Some approaches, as the reduction of powdery mildew inoculum with the hyperparasitic fungus *Ampelomyces* did not work satisfactorily in all regions (for example in central Europe where the chasmothecia are continuously formed starting already from June). Other solutions were only partially validated because the level of the target disease/pest was very low in some of the seasons.
REFERENCES	Links with deliverables and reports on the PURE website

	GRAPEVINE- Solutions against *Botrytis cinerea* **« Results and lessons learnt from PURE »**
	FEBRUARY 2015
OBJECTIVES	The objective of PURE WP6 was to test: *1.* A strategy based on three microbial biocontrol agents having different mechanism of action applied in those specific phenological stages of grapevine when their specific activity is maximized *2.* Agronomic measures based on summer pruning
APPROACH (EXPERIMENTS, ASSESSMENT TOOLS, …)	1. The approach was to select the available microbial biocontrol agents against *Botrytis cinerea*, and schedule their application at specific phenological stage of the plant in order to maximize their efficacy according their mechanism of action. In particular, *Trichoderma atroviride* (efficient colonizer of dead plant residues) was applied at bunch closure, *Aureobasidium pullulans* (efficient competitor for space and nutrients) was applied at veraison when sugar exudates and leaching normally start to be present on the berry surface, and *Bacillus amyloliquefaciens* (direct antagonist) was applied before harvest when a fast effect is normally needed. The efficacy of this strategy was evaluated in term of incidence and severity at harvest and quality of the berries. The survival of each of the microorganisms was also evaluated after application. The trials have been carried out in northern and central Italy in experimental stations because one of the microorganisms was not registered yet. 2. Not only environmental conditions but also bunch architecture and berry structure can influence *Botrytis* bunch rot severity and incidence: grape varieties with compact clusters are more susceptible to rot. Defoliation of the berry zone can help in decreasing the humidity around the bunches and thus reduce the risk of infection. Although summer pruning to reduce the risk of grey mould is a common practice in many European regions, the approach should be validated in areas where it is not a common routine and the wet weather may impair the results. The trials were carried out in Germany in an experimental station, in order to avoid risk of losses in commercial farms during the stage of validation of the method.
PESTS **Please give information about the pests (insects, weeds, diseases, …) studied in the trials of your WP**	 Botrytis cinerea (grey mould)
TECHNICAL RESULTS	1. Trials were carried out in Italy. Unfortunately the pressure of the diseases was low or very low during the 4 years of trials, and this has reduced the possibility of drawing general conclusions on the results. Under conditions of low disease pressure, each of the microorganisms provided the same control of the disease as the full strategy. The approach is anyhow valid in term of reduction of synthetic chemical fungicides (i.e., 3 chemical treatments can be replaced by 3 biofungicides).

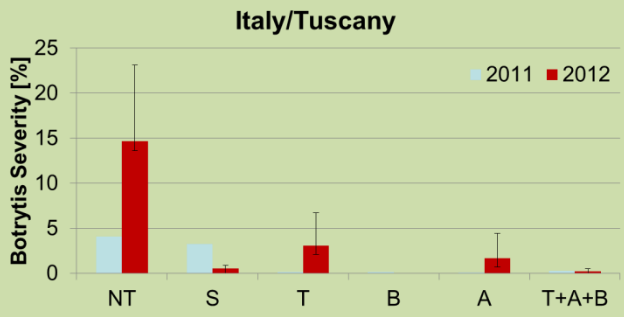


Fig. 1 : Botrytis severity in italian trials for two years in Tuscany

The results obtained in Central Italy in 2011 and 2012 are shown here (Fig. 1) as an example (NT= untreated; S=synthetic chemical; T= T. atroviride, B= Bacillus amyloliquefaciens; A= Aureobasidium pullulans

2. These trials have been carried out in Germany. The results (Fig. 2) in 2011 showed that, with high disease pressure, the defoliation at the phenological stage of flowering was as effective as three fungicide treatments.

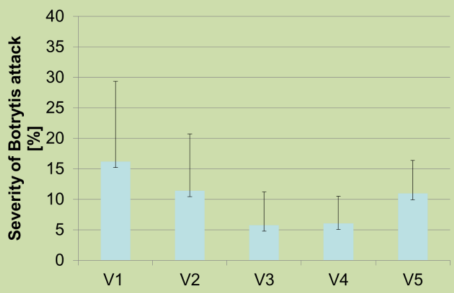


Fig. 2: Botrytis severity in german trials

Cultural Practices Against Botrytis Siebeldingen 2011

V1: non treated control -> no defoliation

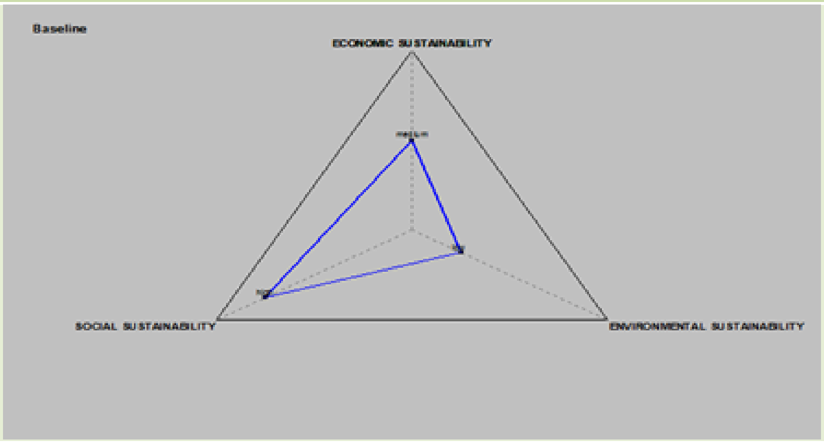
V2: Treatment with blower after flowering (20.06.2011) -> no defoliation

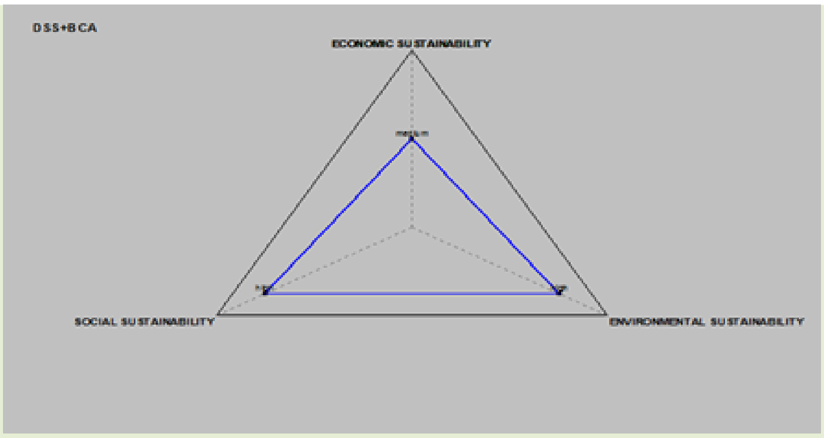
V3: Defoliation of berry zone before flowering (25.05.2011)

V4: Defoliation of berry zone after flowering (08.06.2011)

V5: Defoliation of the flowering zone at beginning of ripening (08.08.2011)

SUSTAINABILITY OF IPM SOLUTIONS



	 *Fig. 3: Overall sustainability assessment with the DEXiPM-Grapevine® tool of biocontrol strategy against botrytis cinerea compared with the conventional system* The ex-post evaluation of the strategy based on microbial biocontrol agents was carried out with DEXiPM (Fig. 3). The conventional strategy (upper graph) is worst in term of environmental sustainability compared to the strategy using the combination of microbial biocontrol agents (lower graph). In term of costs the biofungicides are 10-20% more expensive than the synthetic chemicals, while all the other costs remain identical.
LIMITS AND CONDITIONS OF SUCCESS, ADAPTATIONS	The main limit of the application of a strategy based on the microbial biocontrol agents (biofungicides) is the availability of the registered plant protection product in the country. Unfortunately, these products are not registered in all EU countries so far. The other limiting factor is related to the environmental conditions at the time of spray that could negatively influence the survival and then the efficacy of the microorganisms. A question still open is the level of efficacy of such strategy under high disease pressure.

GRAPEVINE – Method to reduce the inoculum of powdery mildew
« Results and lessons learnt from PURE »

FEBRUARY 2015

OBJECTIVES

To objective was to test:

1. a biological method based on application of a hyperparastite (*Ampelomyces*; commercial product AQ10) to reduce overwintering powdery mildew inoculum (chasmothecia)
2. validate the approach in different climates (Germany, northern and central Italy)

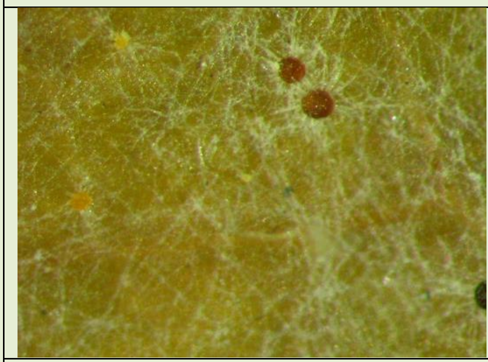
APPROACH (EXPERIMENTS, ASSESSMENT TOOLS, …)

The method is based on the application of Ampelomyces (AQ10; available as commercial biofungicides in several EU countries), which is a hyperparasite of *Erysiphe necator* (Powdery mildew), during the phase of the formation of overwintering inoculum (chasmothecia). This phase is the most susceptible; once the chasmothecia are mature (i.e. black in color) they can only be partially parasitised by *Ampelomyces*. The first part of the work was dedicated to identify the best scheduling of the applications and to develop a monitoring tool to determine such a phase in the vineyard. The second part was dedicated to on farm trials in Germany and northern and central Italy; the effect of two treatments with AQ10 before and after harvest on the parasitization of the chasmothecia and the reduction of the disease in the following season were assessed. Treatments were applied by farmers who actively took part to the trials.

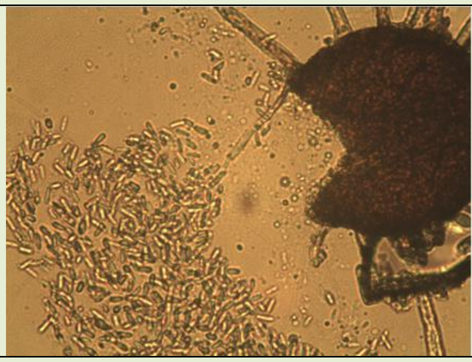
PESTS

Erysiphe necator (powdery mildew)

Chasmothecia of *E. necator* visible on an infected leaf



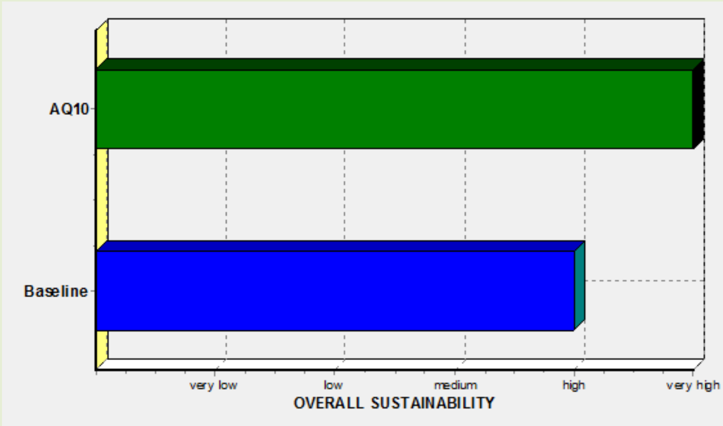
Right stage of application (chasmothecia are not fully mature; white, yellow and light brown)



Ampelomyces parasitizing a powdery mildew chasmothecium: the spores of Ampelomyces are produced instead of the ascospores of E. necator.

TECHNICAL RESULTS

The method reduced the severity of the primary infections of powdery mildew in all the areas under study, except in Germany. The method was not effective in

	Germany because the chasmothecia formation started in June and goes on until the end of the season; therefore, Ampelomyces was applied (around harvest) on a population of already mature chasmothecia. Under these conditions, farmers should theoretically apply the BCA all along the growing season to reduce the inoculum, which is not worth because of the contemporary sprays of fungicides that may kill the conidia of Ampelomyces. In northern Italy, chasmothecia were formed mainly at the end of summer and the parasitization was high. In warm autumns, a second wave was observed in late season. In this case, AQ10 targeted to the first wave of chasmothecia did not significantly reduce the overwintering inoculum. In central Italy, there was high rate of parasitization and a significant delay and/or reduction of the severity of primary infections in the following season. In these cases, growers could delay the first treatment against this disease in spring, thus saving 1-2 treatments or get a lower pressure of the disease and lower damages.
SUSTAINABILITY OF IPM SOLUTIONS	The baseline strategy is already characterised by a high level of sustainability (Fig. 1), but the presence of heavy infections and the consequent need of curative treatments in order to get an economically valuable crop gives the innovative approach a higher overall sustainability mainly due to the increased social and economic sustainability. The environmental sustainability is not affected.  *Fig. 1: Overall sustainability assessment with the DEXiPM-Grapevine® tool of AQ10 strategy against powdery mildew compared with the conventional system*
INNOVATIVE METHODS"	There was a strong interaction with WP9 "Plant-pest-enemies interactions" for the implementation of a formulation of *Ampelomyces* to enhance parasitization. However, for this specific application (reduction of overwintering inoculum) the addition of a conidial germination promoting agent did not increase the efficacy of the treatment, most probably because at the time of application the environmental conditions were optimal for the *Ampelomyces* germination and growth.
LIMITS AND CONDITIONS OF SUCCESS, ADAPTATIONS	Two-fold application of Ampelomyces to reduce the overwintering inoculum of *E. necator* is very successful when the chasmothecia formation occurs in a short period of time (1-2 weeks). In this case, the hyperparasite can affect most of the susceptible chasmothecia and result in a decrease of the overwintering inoculum. In environments where the formation of chasmothecia occurs very early in the season and goes on for several months or occurs in waves, the method would require too many treatments to target all of them, being then not economically sustainable for the farmers. The identification of the right time of application requires visual monitoring of the chasmothecia on leaves. The use of an available model for estimating the maturation dynamic of chasmothecia may help to target properly the moment when to apply the BCA with no or reduced monitoring. In

	case the method is introduced in a new zone, farmers or technicians should define the maturation patterns of chasmothecia to identify whether there conditions of successful application exist.
REFERENCES	Tito Caffi, Sara Elisabetta Legler, Riccardo Bugiani, Vittorio Rossi. 2013 Combining sanitation and disease modelling for control of grapevine powdery mildew, European Journal of Plant Pathology, 135, 4, 817-829.

	GRAPE – NATURAL PESTICIDES AGAINST GRAPE BERRY MOTHS **« Results and lessons learnt from PURE »**
	FEBRUARY 2015
OBJECTIVES	The objectives were: 3. To identify alternatives to chemical pesticides in controlling grape berry moths 4. To evaluate the effects of natural pesticides (e.g. microbial and botanical pesticides) towards other pests and key-beneficials occurring in vineyards
APPROACH (EXPERIMENTS, ASSESSMENT TOOLS, …)	Key elements of trials carried out in on-station experiments: The effects of natural pesticides (Bacillus thuringiensis, azadirachtin, *Beauveria bassiana*, spinosad, pyrethrins) were evaluated in two experimental vineyards located in Central and Northern Italy from 2011 to 2013. The experimental design comprised an adequate number of replicates to analyse data. Sampling of clusters and leaf samples allowed to assess pesticide effects on target and non-target organisms
PESTS	 *Fig. 1: Larva of Lobesia botrana (Lepidoptera: Tortricidae)* The berry moth *Lobesia botrana* is a key pest of grapes in Europe. Berries are damaged by larval feeding, often by grey mould (Fig. 1). In Southern *Europe L. botrana* can develop 3-4 generations per year. Chemical control is usually applied (up to 10 applications per year on table grapes) with serious implications.
TECHNICAL RESULTS	Results of various trials highlight the effectiveness of *Bacillus thuringiensis* and spinosad in controlling berry moth densities and their damage (Figure 2). Their effects on target pests were similar to those of conventional pesticides, e.g. indoxacarb (Fig. 2). *B. thuringiensis* did not show significant effects on other pests or beneficials. In contrast, spinosad reduced the impact of egg-parasitoids of leafhoppers (i.e., *Anagrus* spp.) and of predatory mites (Fig. 3). These side-effects are probably involved in the build-up of leafhoppers in these plots. Sometimes, *B. bassiana* showed additional effects in controlling *L. botrana* when mixed with *B. thuringiensis*. Azadirachtin gave contrasting results over the seasons. Pyrethrins were poorly effective and not selective towards predatory mites.

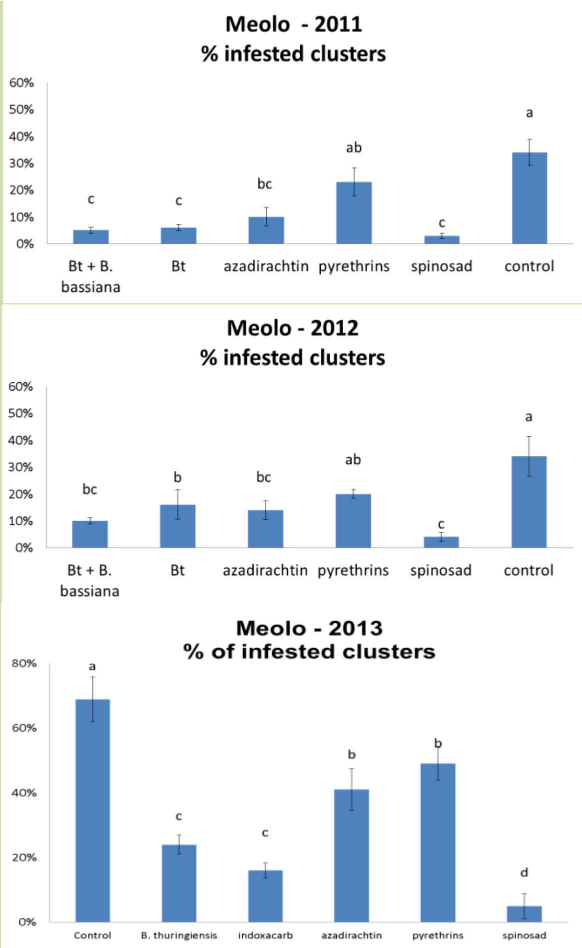


Fig. 2: Effects of natural pesticides on L. botrana damage (2011-2013)

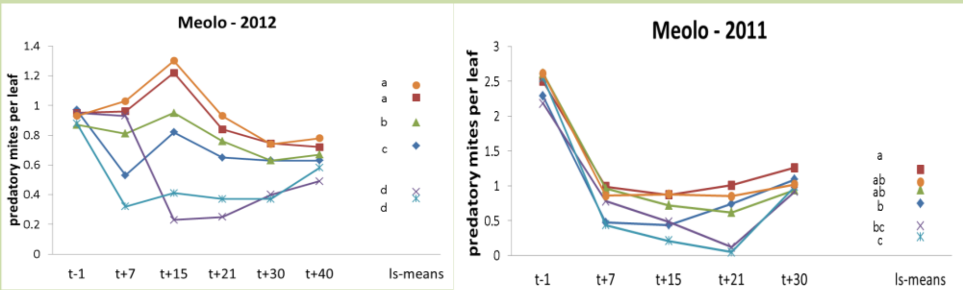


Fig. 3: Effects of natural pesticides on predatory mites (2011-2012)

SUSTAINABILITY OF IPM SOLUTIONS

Different pesticide strategies were compared over the seasons. The most interesting comparison was made in 2012 when strategies based on *B. thuringiensis* (BT) pyrethrins and spinosad were compared. Most of results were affected by the large use of fungicides/herbicides that exceeded that of insecticides. Nevertheless *B. thuringiensis* and spinosad reduced acute risk on fish, *Chironomus* and pollinators compared to pyrethrins. Moreover, *B. thuringiensis* was associated with the lowest risk for pollinators (Tab. 1). The chronic risk for fish and bee was lower when spinosad and especially *B. thuringiensis* were applied (Tab. 1).

Tab. 1: Acute and chronic risk for insecticides used in the three strategies adopted in 2012 at Meolo (fungicide/herbicide use was the same for the three strategies) (From High risk (red), medium, low, and very low risk (dark green))

	Aquatic	Algae	Daphnia	Fish	Lemna	Chironomus	Terrestrial	Earthworm	Bee	Groundwater
Acute risk										
BT	20,003	0,061	20,003	0,600	6,123	0,001	1,212	1,212	0,038	67,087
spinosad	20,003	0,061	20,003	0,600	6,123	0,001	1,212	1,212	0,462	67,087
pyrethrins	20,003	0,061	20,003	2,882	6,123	0,508	12,846	1,212	12,846	67,087
Chronic risk										
BT	2,407	0,041	2,407	0,394	1,577	0,000	12,070	12,070	0,229	13,417
spinosad	2,494	0,041	2,494	0,394	1,577	0,000	12,070	12,070	2,803	13,417
pyrethrins	3,493	0,041	3,493	1,876	1,577	0,048	56,268	12,095	56,268	13,417

In 2012, the gross yield was slightly higher and the pest management cost lower in *B. thuringiensis* strategy. As a consequence, the latter was the most environment-friendly and money-saving strategy in that season.

Tab. 2: Volumes, prices and values of the different pest management strategies adopted in 2012 at Meolo.

Description	BT			pyrethrins			spinosad		
	Volume (ton/ha)	Price (€/ton)	Value (€/ha)	Volume (ton/ha)	Price (€/ton)	Value (€/ha)	Volume (ton/ha)	Price (€/ton)	Value (€/ha)
Conventional DOC wine premium class (Cabernet)	13,54	386,8 €	5.237,7 €	13,21	387,3 €	5.116,5 €	12,9	364,1 €	4.696,5 €
Gross yield	13,5		5.237,7 €	13,2		5.116,5 €	12,9		4.696,5 €
Material costs	Freq.	Rate	Costs	Freq.	Rate	Costs	Freq.	Rate	Costs
Insecticides (TFI)	2,0	19,0 €	38,0 €	2,0	45,0 €	90,0 €	2,0	80,0 €	160,0 €
Labour/equipment costs	Freq.	Rate	Costs	Freq.	Rate	Costs	Freq.	Rate	Costs
Insecticide sprays (no.)	2,0	50,00 €	100,0 €	2,0	45,00 €	90,0 €	2,0	45,00 €	90,0 €
Pest management cost			138,0 €			180,0 €			250,0 €
Returns for covering other costs			5.099,7 €			4.936,5 €			4.446,5 €

In 2013, strategies based on BT, spinosad and indoxacarb were compared. No differences emerged regarding environmental sustainability. The cost-benefit analysis highlighted the indoxacarb-based strategy as the most money-saving. However, it should be stressed that this product is classified as noxious for human health. BT strategy was associated with lower pest management costs and higher return compared to spinosad.

LIMITS AND CONDITIONS OF SUCCESS, ADAPTATIONS

This strategy requires an accurate monitoring of *L. botrana* phenology (in particular oviposition) to identify the best time for applications. Attention should be given to formulate (date of production and conservation), weather conditions, water quality (pH) and the volume to ensure the maximum contact of the suspension with berries. BT does not control other grape pests but is the most selective among natural pesticides.

REFERENCES

C. Duso, M. Lorenzon, A. Pozzebon, D. Fornasiero, P. Tirello, B. Costa, M. Benanchi, S. Simoni, E. Gargani, S. Guidi, F. Tarchi, B. Bagnoli - Evaluation of natural pesticides in controlling grape berry moths and their side-effects on grapevine fauna. IOBC/WPRS Working Group "Integrated production and protection in viticulture", Ascona (Switzerland), 13-17 October 2013 (Book of abstracts).

	GRAPEVINE – Decision support systems « Results and lessons learnt from PURE »
	FEBRUARY 2015
OBJECTIVES	The objective was to test: 1. A Decision Support System for scheduling fungicide applications against downy and powdery mildews in different grape-growing area of Italy (Po Valley, Tuscany and Trentino-Alto Adige)
APPROACH (EXPERIMENTS, ASSESSMENT TOOLS, …)	The application of a Decision Support System (DSS) named vite.net developed by Università Cattolica del Sacro Cuore (Italy) was applied to schedule fungicides applications against powdery and downy mildews. Two strategies were compared in 9 farms in different grape-growing areas (1 in Piedmont, 1 in Lombardy, 1 in Emilia-Romagna, 1 in Trentino Alto-Adige and 5 in Tuscany) for 3 seasons (2012, 2013 and 2014). The data presented are the average of all the combinations (locations x years). • **Baseline strategy:** IPM or Organic management of high quality vineyards characterized by low production regimes according to the DOCG/DOC quality wine appellation. Fungicide treatments were performed following indications of the advice provided by the Regional Plant Protection Service (RPPO) for the specific area. IPM fungicides were selected according the limitations indicated by each RPPO. In Organic farming regime only sulphur and copper were used to protect the vines. • **Innovative strategy:** IPM or Organic management of high quality vineyards characterized by low production regimes according to the DOCG/DOC quality wine appellation. Fungicide treatments were performed by the growers according to their own understanding of the information provided by the DSS. IPM fungicides were selected trying to use to lowest impacting products, in respect of the limitations indicated by each RPPO. In Organic farming regime only Sulphur and Copper were used to protect the vines.
PESTS	 *Erysiphe necator* (powdery mildew) symptoms on cluster and leaves  *Plasmopara viticola* (downy mildew) symptoms on cluster and leaves
TECHNICAL RESULTS	The fungicide schedule for preventing downy and powdery mildew on grapevine in Italy lead on average to 11.1 treatments in the baseline and 9.9 in the innovative strategy, respectively, under Integrated Pesticide Management regime (Fig. 1), while 16.2 and 13.2, respectively, for Organic management (data not shown). The use of the DSS allowed the farmers to calibrate the amount of fungicides applied at any treatment and this resulted in an average reduction of the TFI from 22.3 to 15.3 in IPM and from 29.3 to 16.5 in Organic (data not shown) and a consequent reduction in disease management costs of about 200€ per hectare per season.

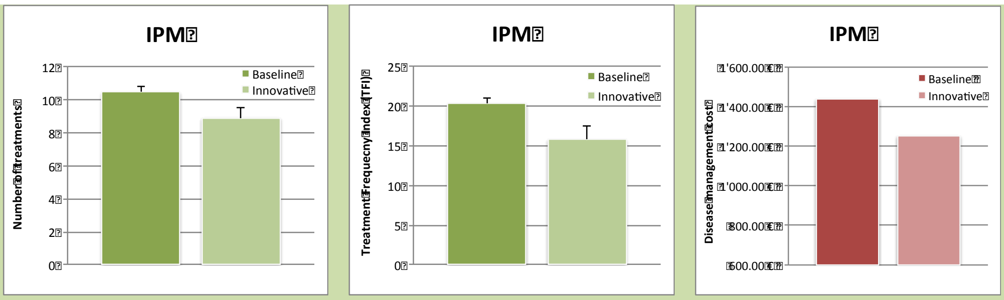


Fig. 1: Number of treatments, treatment frequency index (TFI) and cost of disease management obtained over three years (2012-2014) of on-farm experiments under different conditions across Italy (Trentino Alto-Adige, Piedmont, Lombardy, Emilia-Romagna and Tuscany)

SUSTAINABILITY OF IPM SOLUTIONS

The "overall sustainability" of the IPM system moved from high in the baseline to very high in the innovative approach (Fig. 2). This enhancement of sustainability was due to the increase of both social and environmental sustainability (Fig. 3A). The job gratification following the application of the DSS, and thus the increased knowledge and awareness of the farmer during the decision making process, moved from medium to high (Fig. 3B).

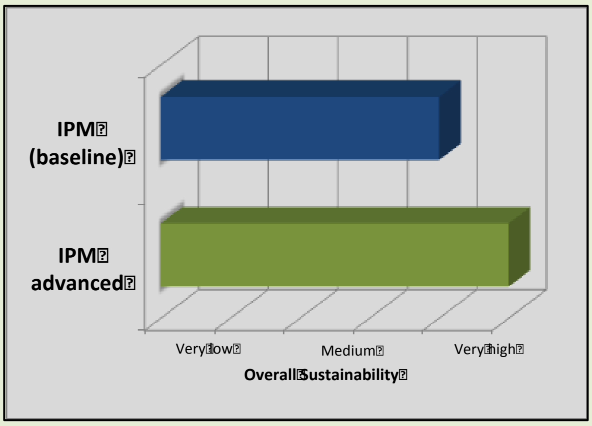


Fig. 2: Overall Sustainability comparison between the IPM (baseline) and the IPM innovative system (i.e. adoption of a DSS for managing fungicide scheduling against downy and powdery mildews) tested with the ex-post version of DEXiPM in Italy (input data were the averages of all the farm for all the season).

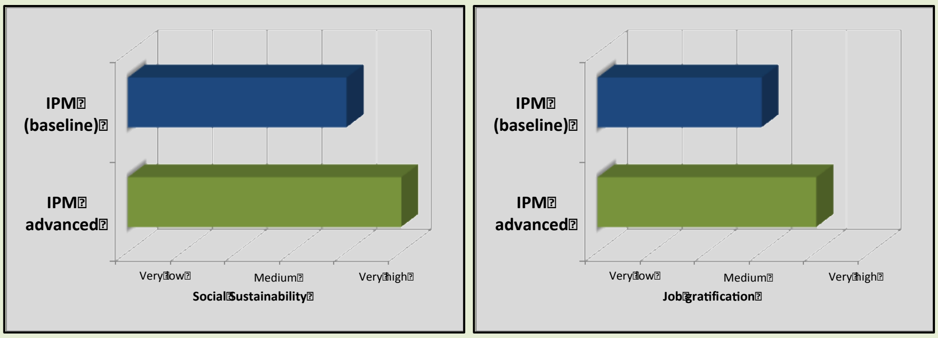


Fig. 3: Social Sustainability (A) and Job Gratification (B) comparison between the IPM (baseline) and the IPM innovative system (i.e. adoption of a DSS for managing fungicide scheduling against downy and powdery mildews) tested with the ex-post version of DEXiPM in Italy (input data were the averages of all the farm for all the season)

Moreover, the environmental sustainability moved from medium of the baseline IPM to high with the application of the innovative tool (Fig. 4A). The innovative IPM strategy tested, in fact, allowed a global saving of fungicides due both to the reduction in the number of treatments and in the dose calibration (TFI). The application of the DSS allowed the growers also to be prepared to what is going on in the field and thus choose time to time the less impacting active ingredients. A direct consequence of all these effects is a dramatic reduction of the pressure on biodiversity, both aerial and terrestrial (Fig. 4B).

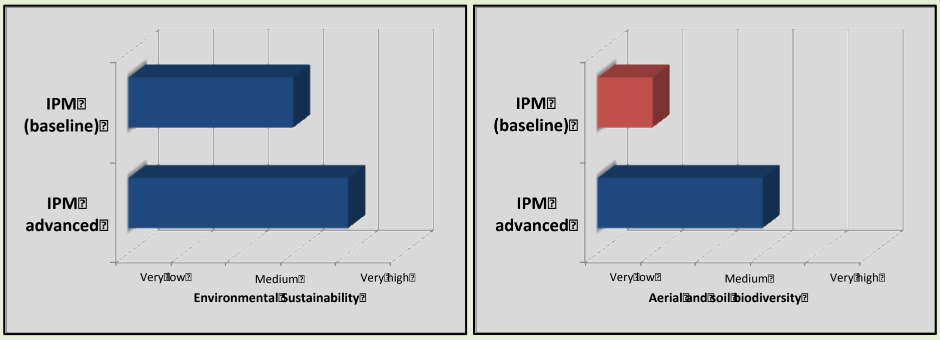


Fig. 4: Environmental Sustainability (A) and Aerial and Soil Biodiversity (B) comparison between the IPM (baseline) and the IPM innovative system (i.e. adoption of a DSS for managing fungicide scheduling against downy and powdery mildews) tested with the ex-post version of DEXiPM in Italy (input data were the averages of all the farm for all the season

LIMITS AND CONDITIONS OF SUCCESS, ADAPTATIONS

The overall sustainability of the baseline system, in the case studies of PURE, can be considered of “high” quality in the case of IPM and of “very high” quality in the case of Organic viticulture. In many cases, in particular for organic management, the baseline strategy is the application of the best practices currently available and thus, the further improvement proposed by PURE, results in a little increase of the sustainability of the system. The real impact on the viticultural sector of the proposed innovation may be higher because the best practices are currently not used by all the farmers.

The innovative application of a DSS showed that a further improvement of the environmental quality is possible, with efficient disease control. Costs of implementation of the innovative approach are fully compensated by both the reduction of number of chemical treatments and TFI. Moreover, a significant reduction in the disease management costs was reached.

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

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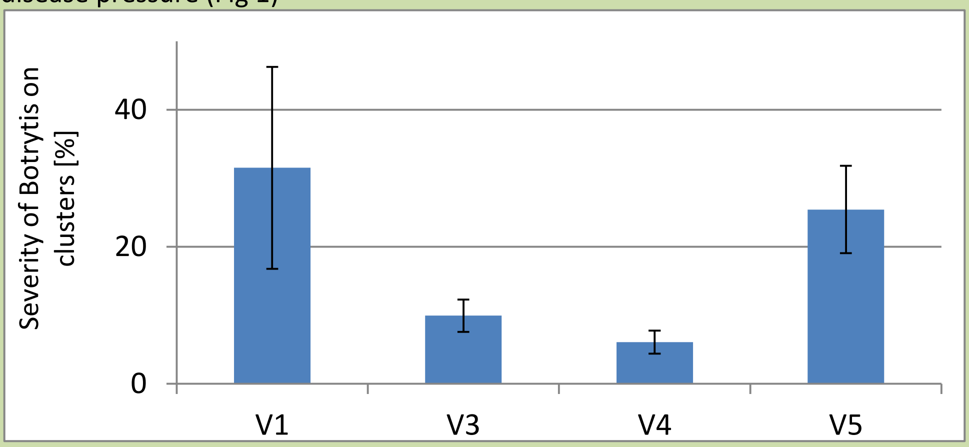
PURE Deliverables D6.1, D6.2 and D6.3

	GRAPEVINE – IPM solutions based on agronomic practices against *Botrytis cinerea* and sour rot « Results and lessons learnt from PURE »
	FEBRUARY 2015
OBJECTIVES	The objectives were: • To identify alternatives to chemical botryticides against *Botrytis cinerea* and sour rot, • To evaluate cultural methods like the defoliation of the berry zone during the phenological stage of flowering.
APPROACH (EXPERIMENTS, ASSESSMENT TOOLS, …)	Key elements of trials carried out in on-station experiments: The effects of different defoliation regimes were evaluated and compared to classical botryticide treatments. The trials were done in a vineyard in south-western Germany from 2011 to 2013. The experimental design comprised randomized plots of 25 vines each in 4-fold repetition. Sampling of clusters few days before harvest allowed to assess differences in the severity of Botrytis or Sour rot. Defoliation can lead to a changed – i.e. more losse-berry structure, when carried out during the phenological stage of flowering. Later in the season it can reduce the rot severity by a better ventilation of the clusters.
PESTS	 Left: Compact cluster with crushed berries and sour rot. Right: Grey Mould (*Botrytis cinerea*) on grape cluster
TECHNICAL RESULTS	Fig 1 shows the results of the different defoliation regimes in the year 2013, while Fig.2 presents the severitiy of Botrytis attack after different conventional treatments with Botryticides in the same year. Both experiments where done in the same plot. While the maximum of three Botryticide treatments reduced the Botrytis severity only slightly (Fig. 2), defoliation of the berry zone around the phenological stage of flowering turned out to be highly effective under the same disease pressure (Fig 1)  *Fig. 1: Significant effect of defoliation at flowering stage as a cultural method to control Botrytis cinerea and Acid Rot (variety: Chardonnay; location: Siebeldingen; year: 2013). Error bars indicate SD. V1: non treated control → no defoliation; V2: -; V3: Defoliation of berry zone before flowering; V4: Defoliation of berry zone after flowering; V5: Defoliation of the flowering zone at beginning of ripening.*

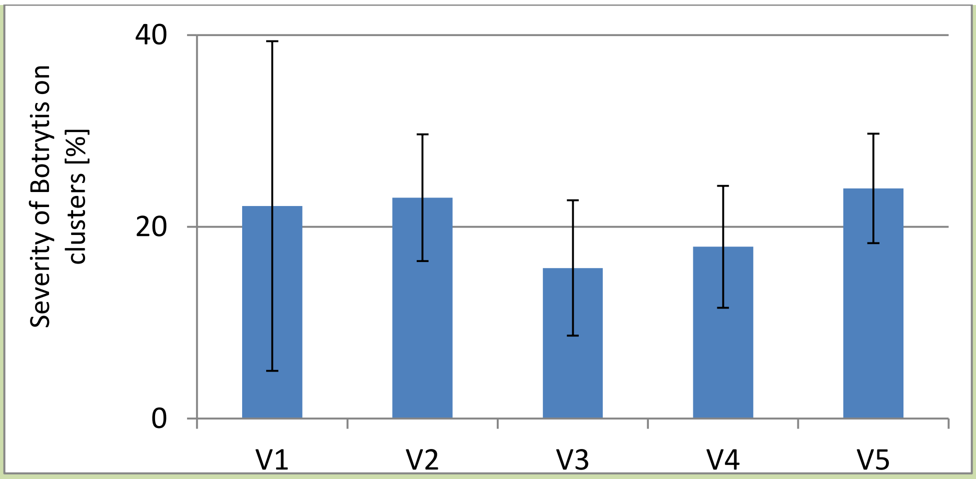


Fig. 2: Non significant effect of different numbers of Botrytis treatments (variety: Chardonnay; location: Siebeldingen; year: 2013). Error bars indicate the standard deviation of the four replications. V1: non-treated control ; V2: 1 treatment: after flowering (Switch); V3: 2 treatments: after flowering + before grape closure (Switch, Cantus); V4: 3 treatments: after flowering + before grape closure + beginning of ripening (Switch, Cantus, Switch); V5: 1 treatment: before grape closure (Cantus)

Swich: 37,5 % Cyprodinil 25,0 % Fludioxonil ; Cantus : 50% Boscalid

SUSTAINABILITY OF IPM SOLUTIONS

Defoliation leads to a relevant improvement in the environmental quality and is essentially linked to a reduced soil compaction risk and reduced pesticide emission in the air (Fig. 3).

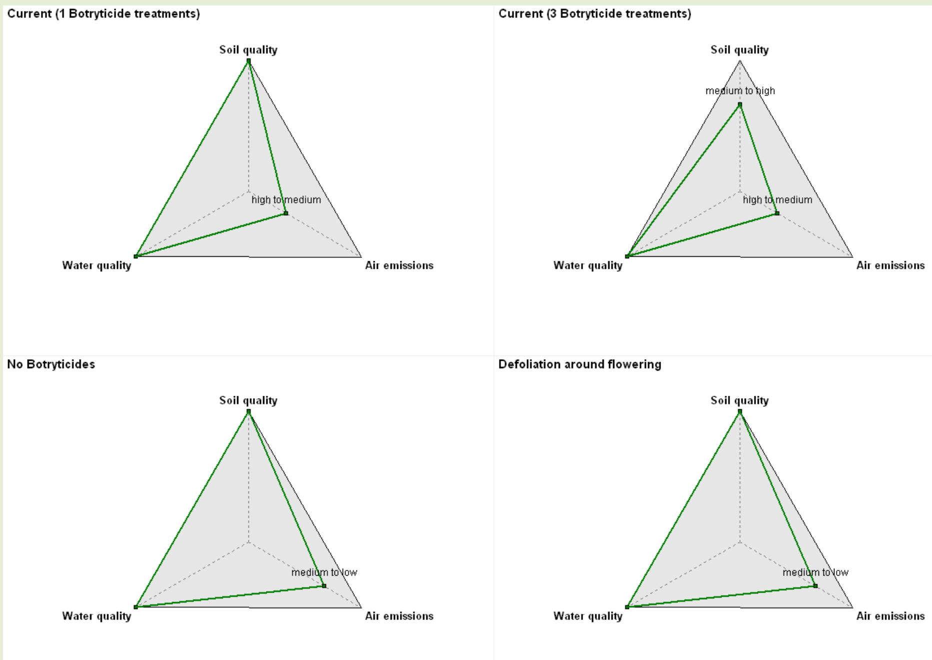


Fig. 3: Botrytis control – DEXIPM-Grapevine ® output for environmental quality with respect to different numbers of Botryticide applications and defoliation around flowering

Bringing together the trial results and our expert knowledge we can conclude that the IPM solution “defoliation of the berry zone around the phenological stage of flowering” brings advantages for the environment when compared to 3 botryticide treatments. Winegrowers would pay a lot to get healthy grapes without Botrytis. An advantage of mechanical defoliation is that the production quality and quantity is constantly high over the years and the risk of extraordinary

	losses is minimized. Actually there is a trend in viticulture that only quality wine producers survive on the market. Quality production is always linked to yield reductions which lead to better qualities. These reductions can comprise a 50% yield loss with a correspondent gain in quality. With this background defoliation of the berry zone, in this way replacing 3 botryticide sprayings and at the same time increasing the quality of the harvested grapes, is a success story.
LIMITS AND CONDITIONS OF SUCCESS, ADAPTATIONS	The main limit for the application of the cultural technique "defoliation of the berry zone around the phenological stage of flowering" might be a yield loss of around 8 %. On the other hand quality wine production often requires a certain yield reduction to achieve good wine quality. As there are also machines to conduct the defoliation automatically we think the labor input is justified. The efficacy of this technique in compact grape varieties turned out to be more effective than classical botryticides.
REFERENCES	Links with deliverables and reports on the PURE website

GRAPEVINE – Comparison of low input cropping systems based on DSS, biocontrol and resistant varieties
« Results and lessons learnt from PURE »

FEBRUARY 2015

OBJECTIVES

The objectives were:

- To design various prototypes of grapevine cropping systems with a significant reduction of pesticide use (over 50%), integrating a set of coherent techniques contributing to the regulation of pests and diseases
- To assess their performances and sustainability within a network of experiment stations located in 3 contrasted regions of France

APPROACH (EXPERIMENTS, ASSESSMENT TOOLS, …)

The design of prototypes was participative, with the contribution of extensionists and scientists from various regional and national institutions (Metral et al, 2012; Lafond et al, 2013). Each prototype was based around an original option: (1) minimizing applications and doses with decision support systems (DSS), (2) applying no pesticide by using resistant varieties and (3) combining a range of biocontrol tools.
Prototypes were implemented in INRA experimental farms in Angers (Loire Valley, center of France), Bordeaux (Atlantic region), and Montpellier (Mediterranean region).
Assessment was carried out on specific aspects such as environmental risk (Synops) and economic performance (Cost-Benefit Analysis) and also on the economic, social and environmental dimensions of sustainability (DEXiPM).
After the project, prototypes can be re-adjusted before validation and dissemination.

PESTS

The whole pathosystem was considered in each region. Dominant diseases were downy (*Plasmopara viticola*) and powdery (*Erysiphe necator*) mildews, and *Botrytis cinerea,* and the dominant pest was berry moth (*Lobesia botrana*).


downy mildew


powdery mildew


grey mould


berry moth

TECHNICAL RESULTS

From the first year of experimentation (2012), the treatment frequency index (TFI) was reduced by at least 50% in over 40% of the tested prototypes (Some results in Fig. 1). This reduction in pesticide use resulted primarily from improved control strategies and control of the application of plant protection products.

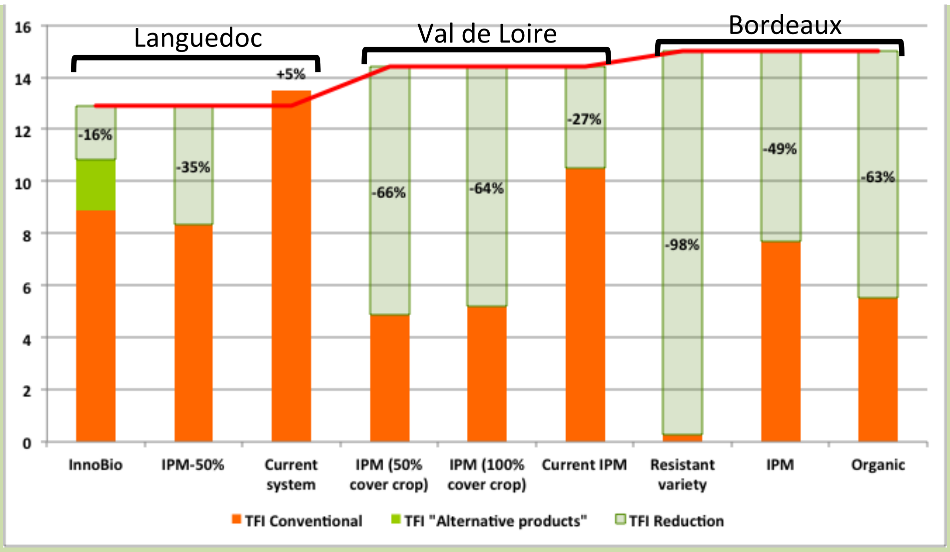


Fig. 1: TFI reduction in French farming system' experiments (average on 3 years)

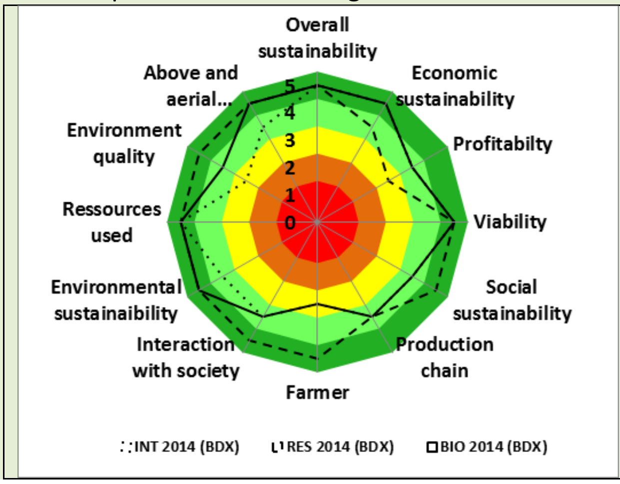
Two decision support systems were used: (i) Mildium (Deliere et al, 2014) was designed as a set of decision rules to regulate the number of applications against downy and powdery mildews; (ii) Optidose (David & Heinzlé, 2009) aims at reducing the applied pesticide dose in relation to the development of the grapevine canopy. In all places, the strategies based on these two DSS were effective in reducing pesticide use and the associated environmental risk compared to conventional management. Yet Synops identified some acute risks that differed among the places. The production costs did not differ significantly from conventional management, and the gross margin could occasionally be higher.

Strategies based on resistant varieties definitively suppressed pesticide use and the resulting environmental risks. Yet the total production costs stayed at the same order of magnitude as conventional or DSS-based strategies.

At last, the strategy based on the exclusive use of biocontrol reduced both the acute and chronic risks compared to conventional and DSS-based strategies. Yet the production costs were higher, and the gross margin severely reduced.

SUSTAINABILITY OF IPM SOLUTIONS

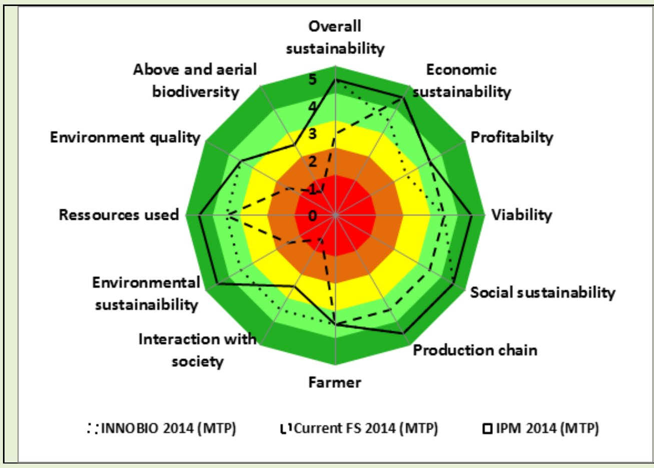
The three grapevine protection strategies assessed with DEXiPM-Grapevine ® in Bordeaux exhibited the same good global sustainability (Fig. 1). Yet, the strategy based on resistant varieties has an environmental performance similar to organic and higher than the DSS-based strategy. Its economic performance was lower and its social performance was higher than the two other strategies.



---- resistant variety
— organic
●●●● DSS

Fig. 1: Three grapevine protection strategies assessed with DEXiPM-Grapevine ® in Bordeaux (France) (2014)

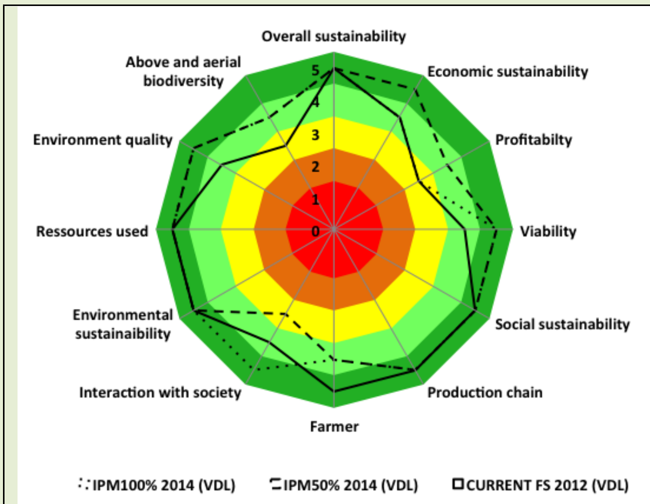
In Montpellier, the DSS-based and biocontrol-based strategies both improved the three pillars of sustainable development, compared to the conventional strategy of grapevine production (Fig. 2). The DSS-based strategy performed slightly better for the economic and environmental dimensions.



---- conventional
— DSS
.... Biocontrol

Fig. 2: DSS-based and biocontrol-based strategies compared to the conventional strategy of grapevine production in Languedoc (Montpellier, France) (2014)

The overall evaluation of the systems is very good, as was the evaluation of the reference (Fig. 3). However, we can note that Economic durability is lower on the reference than on the Intermediates IPM one, despite lower yields in the IPM50% cover crop system, which causes lower Profitability. But the Viability of the reference system is lower (Good instead of Very good) on the reference, due to a higher dependence to plant protection products.
Concerning Social durability, the main difference is for IPM 100% cover crop system a lower “Interaction with society” evaluation, due to an overall fewer number of work hours, involving a lower contribution to employment.
For environmental durability, the main difference is a higher impact on aerial and water biodiversity in the reference, which is coherent with the results of the SYNOPS assessment



---- IPM (50% cover crop)
●●●● IPM (100% cover crop)
— IPM current

Fig. 3: IPM strategies with 50% and 100% covercrop compared to the current IPM strategy of grapevine production in Val de Loire (Angers, France)

LIMITS AND CONDITIONS OF

The process of cropping system design by prototyping is iterative. The three

SUCCESS, ADAPTATIONS	options (resistant variety, DSS, biocontrol) that have been explored in the framework of the PURE project all led to a reduction of pesticide use and clearly improved the environmental performance compared to conventional management. Yet the limited number of available resistant varieties seriously limits their adoption by grape growers, and biocontrol remains an expensive approach and did not lead to a satisfying gross margin. These promising approaches should then be improved, and assessed again. The DSS-based strategy appears to be reliable; its labour cost should still be tuned at farm scale, as it relies on the frequent observation of indicators needed in decision rules.
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3. Conclusion

Several IPM solutions have been tested in Europe. The solutions are not simple treatments, but new concepts and approaches. The objective is the combination of different techniques having partial efficacy on pests and diseases in a systemic approach. It is possible to highly reduce the pesticide use with DSS tools based on field scouting and modelling. Additional and alternative solutions with combination of biocontrol agents, reduction of inoculum and agronomic practices have to be used to promote innovative approaches and to increase pesticide reduction. At the end of the PURE project we can conclude that it is not possible to make a unique recommendation, but that IPM solutions should be adapted and combined according to the socio-economic and environmental condition of each single grape growing region in Europe.