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IPM Innovation in Europe

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Book of Abstracts

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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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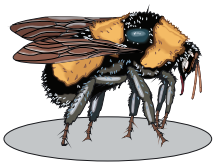

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PERSPECTIVES ON THE IMPLEMENTATION OF IPM IN EU: THE CONTRIBUTION OF PURE

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The FP7 PURE project aimed (i) to provide practical IPM solutions – combinations of tactics and strategies – to reduce reliance on pesticides, based on integrative research; and (ii) to deliver scientific knowledge to design future IPM solutions, based on innovative research in challenging fields: pest evolution, plant-pest-enemy interactions, soil and landscape ecology and emerging technologies. To reach these objectives, the PURE team (22 partners distributed all over Europe) studied various pests (pathogenic agents, animal pests, weeds) in key European farming systems: annual arable farming systems (wheat-based and maize-based, field vegetables with cabbage as a model crop), perennial systems (pome fruit and grapevine) and protected crops, with tomato as a model crop. The design of IPM solutions relied on a wide variety of tactics such as biocontrol products in field vegetables, apple or grapevine, and strategies such as diversified crop sequences in wheat- and maize-based farming systems. On three case studies, a co-innovation approach was applied to improve the involvement of stakeholders in the design process. IPM solutions were tested and compared to current practices on-station and on-farm and assessed by several tools developed or adapted during the project, which include DEXiPM to assess sustainability on a multi-criteria basis, SYNOPS, a multi-level pesticide risk assessment tool, and a cost-benefit analysis. Efficient alternatives to pesticides, i.e. biological, cultural, physical (e.g. mechanical weeding), and genetic (e.g. cultivar mixtures) control methods and their combination were identified. Promising results were obtained even if the IPM systems did not always allow the best outcome for all sustainability criteria simultaneously. Newly identified IPM systems achieved better environmental performances compared to current systems, with efficient pest control, but their costs were often higher even if it was not systematic. In addition, significant methodological breakthroughs were achieved with regards to the modelling for sustainable management of crop health. Pest evolution studies warned against reliance on a single biocontrol agent and suggested pathways for durable plant resistance, in particular the use of single gene strategies that can act as “stepping stones” for breaking the resistance provided by pyramiding strategies. The works on plant-pest-enemy interactions enabled progress in the identification of biocontrol products and in means to make them more effective. Ecological engineering strategies showed potential, leading to shifts in pathogen suppressing components of the soil community at the field scale and the suppression of pest populations in response to crop and land use patterns at the landscape scale. A wide range of technological tools to help implement IPM was designed or adapted in relation to the activities on farming systems, from monitoring systems at different scales to precision spraying techniques to reduce the amount of pesticides. On the whole, the PURE project provided promising results, models, knowledge, and practical tools and approaches to help implement IPM. In addition to their applications, the PURE results suggest various prospects such as designing public policies to encourage IPM adoption, fostering the design of IPM as a system approach, promoting both ecological and technological knowledge and tools for pest control, or developing co-innovation approaches and tools to facilitate the implementation of IPM with stakeholders.

INTEGRATED PEST MANAGEMENT IN GREENHOUSE CROPS IN POLAND

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In Poland the total area of greenhouse crops ranges from 6500–7000 ha, depending on the fluctuation in the area of crops under plastic-covered greenhouses over several years. The crops under plastic-covered greenhouses occupy 65% of the total area of greenhouse crops. Greenhouses occupy 2000 ha, including: 1000 ha of greenhouse grown tomato; 500 ha of cucumbers and ornamental plants; 500 ha of other crops. In the majority of cases, integrated plant protection (IPM) is used on large areas of vegetable crops, especially in modern greenhouse farms, as well as on tomato and cucumber crops grown in older types of greenhouses or plastic-covered greenhouses. In addition, IPM is used partially in ornamental plants, herbs and seedlings' production. At present 20–30% of the area of greenhouse crops is protected with the use of integrated methods including multiple treatments with biological control agents, as well as other non-chemical methods. Many plant pests such as: whiteflies, spider mites, trips, aphids leaf miners, butterfly caterpillars (including *Tuta absoluta*), dark-winged fungus gnats and pathogens causing root rot are controlled through the use of bio-control agents. All of the natural enemies which are used as bio-control agents in other European countries are authorized and registered for the protection of Polish crops. However, for the control of plant pathogens the only registered bio-products are-ones which contain the antagonist fungi *Phytium oligandrum* and *Coniothyrium minitans.* The wide availability of entomopathogenic agents is due to the fact that their registration as bio-control agents is not required. The required registration of micro bio-products (fungi, bacteria and viruses) and of plant extract products, definitely limits their use in Poland. The level of knowledge of Polish food producers regarding integrated plant protection is especially noteworthy. Apart from the professional advice from experts representing trade companies involved in the distribution of bio-products and specialists from government-institutions such as the Institute of Plant Protection – National Research Institute in Poznan, larger horticultural farms employ experts or expert teams on plant protection including biological and integrated control.

PERSPECTIVES ON THE IMPLEMENTATION OF IPM IN EU – THE ADVISORY PERSPECTIVE

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Some major drivers for IPM in European countries are:

1. availability of pesticides: certain old actives are being phased out over the coming years and only few new actives are introduced,
2. increased problems with pest, disease and weed resistance to pesticides,
3. availability of well-documented thresholds and monitoring, forecasting and decision support systems,
4. new developments in non-chemical IPM tools, and
5. requirements from markets and consumers

As neither of the above-mentioned factors are constant, the process of implementation of IPM will be dynamic, where farmers/growers will continually strive to adopt those tools that are relevant and cost effective on their farm. Advisers will be instrumental in that process.

Many IPM tools are more variable in efficacy than chemical pesticides, and therefore it is important that advisers and farmers engage into a learning process in order to ensure that the transition goes smoothly without crop failures etc. Also, it is important to ensure that overall there will be something in IPM for the farmers, otherwise adoption will be slow, and the job of advisers impossible.

Education and extension are important activities to build awareness of IPM tools. Many advisers will need better technical skills ("train the trainer") as well as new non-technical skills in order to support IPM implementation at the farm level. Experiences from e.g. the EU Leonardo project confirm these statements and outline new roles and tools for advisers. One common tendency is for the role of advisers to change from being "experts giving a prescription" towards acting as "facilitators of innovation and learning processes".

In Denmark, we have based IPM implementation on a central information system, IPM demonstration farms and focused IPM-advisory packages offered a large number of farms. Other EU member states are backing IPM adoption in other ways. Experiences from the Danish activities regarding IPM implementation suggest that even though IPM is about systems thinking, it is still important to be concrete in advisory activities, and to identify which tools in the IPM toolbox are relevant on a certain farm. The chance of a successful implementation of IPM increases when growers and advisers engage with other stakeholders in a process where the cropping system is gradually improved, and where limitations can be identified and corrected. Small-scale on-farm experimentation is very useful in that respect. We have also experienced that an increased grower awareness of IPM is a requirement for successful implementation, and that it can sometimes be difficult to measure changes in IPM implementation on the short term. However, so far we have not seen farmers that could not improve their practices to some extent.

A major concern for many advisers regarding IPM is liability. When advising about integrated solutions that are less certain than pesticides, communicating uncertainty to farmers, and making sure that farmers will accept solutions that are more variable will become an important aspect.

IPM implementation calls for a better collaboration between farmers, advisers, stakeholders and scientists to ensure an efficient development of new IPM tools for future farming. The need for innovation-oriented IPM research will continue to be great in the years to come.

THE POLICY PERSPECTIVE – HOW EU MEMBER STATES PROMOTE IPM IMPLEMENTATION

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The Directive on the Sustainable use of pesticides (2009/128/EC) requires Member States to promote Integrated Pest Management (IPM) and low pesticide-input pest management. They shall describe in their National Action Plans how they ensure that the general principles of integrated pest management are implemented by all professional users.
The National Action Plans of a broad number of countries were analysed as to how the goals and measures contribute and actively promote IPM implementation at farm level. Several MS have set up networks of demonstration farms, initiated specific training courses on IPM for advisors and included IPM and information on biological and non-chemical alternatives in their professional training curricula. An analysis of national research programmes indicates future priorities which address research which will be conducive to IPM implementation such as breeding for resistance and resistance management, cropping system research, adaptation of threshold models, advanced decision support systems and biological control.
The presentation will describe in detail selected national initiatives to foster IPM uptake.

FIRST EXPERIENCES FROM PRACTICAL IMPLEMENTATION OF THE NATIONAL ACTION PLAN IN POLAND

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On 6th May 2013, Poland adopted the National Action plan to reduce the risk associated with the use of plant protection products (NAP), to fulfill the obligations of the Directive 2009/128/EC. Prior to the adoption of the Directive 2009/128/EC, legislation of the European Union had not set detailed rules for the application of plant protection products, leaving considerable freedom in this area to individual Member States. However, many Member States of the European Union, including Poland, introduced national legal solutions, as well as non-legislative measures, to reduce the risk associated with the use of plant protection, including those regarding:

1) compliance with the requirements of integrated pest management by professional users of plant protection products,
2) promoting the use of non-chemical methods of pest management and reducing the dependency of crop production on the use of chemical plant protection products,
3) dissemination of knowledge regarding the safe use of plant protection products.

Analysis of actions taken so far in this area, with particular focus on the food safety and balance between the social, economic and environmental needs allow to establish two main objectives of the NAP:

1) **dissemination of general principles of integrated pest management,**
2) **prevention of risks associated with the use of plant protection products.**

A key objective for Poland in the implementation of the National Action Plan is to promote the general principles of integrated pest management. Full implementation of these principles, in particular by promoting non-chemical plant protection methods, will reduce the dependence of crop production on chemical plant protection products. As a result of the application of best practices on the use of plant protection products, the risks associated with their use will be limited to a minimum.

In order to achieve the main objectives of the National Action Plan, the measures to reduce the risks associated with the use of plant protection products will continue, although some of them will be modified. Accordingly new measures will be taken, in the scope shown later in this document. All measures have separate targets and timetables for their implementation, as well as indicators to monitor their implementation.

Presently, we expect to harmonize within the EU control procedures in integrated pest management, what have to be understandable to farmers and advisors.

EUROPEAN CROP PROTECTION ASSOCIATION (ECPA) FULLY COMMITTED TO IPM THANKS TO INNOVATION AND THE ENGAGEMENT OF ITS MEMBERS

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ECPA (European Crop Protection Association) and its member companies and associations support sustainable agriculture to produce sufficient, affordable food and fiber in an environmentally and socially sensitive manner. We are committed to Integrated Pest Management (IPM) – an economically viable ,environmentally sound and socially acceptable approach to crop protection – as defined by the international Code of Conduct on pesticides management and the annex 3 of the sustainable use directive 128/2009/CE.
Our members companies, investing an average of 10% of their turnover in the research and development of new solutions – chemical based, macro organisms, microorganisms, natural substances, semiochemicals, decision making tools, services – which provide tools to farmers to combine cultural, biological and chemical measures to manage diseases, insects, weeds and other pests. Company members, national associations and ECPA are cooperating with partners in order to develop programs as well as training on the sustainable use of crop protection solutions, in order to get the require competence in the 3 steps of IPM: prevention, monitoring, intervention.
On top of that, significant progress has been made on the products (products more specific, safer formulations, mode of action/resistance management, application techniques) and the use phase/stewardship. The Hungry for change initiative, launch in 2011, which consist of the implementation of 12 projects related to Food, Water, Health and Biodiversity, involving partners – technical advisors, farmers, distributors, government and non-government organizations, scientist,… -is also targeting the impact and risk reduction of the crop protection activity, answering the objective of the IPM principle. Among those projects, the Safe and Sustainable Use Initiative is running in 16 countries and provide farmers and operators with tools for the safe us of crop protection products.
ECPA is convince that IPM is part of the solution to produce more crops on existing farmland, improves farmer livelihoods and conserves nonrenewable resources; so IPM provides multiple benefits for society and environment.

THE INSTITUTIONAL CONTEXT OF THE PURE CO-INNOVATION PILOTS

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The involvement of farmers in research processes is widely seen as an essential aspect to foster the success of research for sustainable agriculture. This paper focusses on such farmer participatory research projects carried out in the domain of Integrated Pest Management (IPM).
Over the past few decades, much work has been done on farmer participatory research in agriculture. One of the returning messages in this extensive body of literature is the importance of the institutional context to understand the dynamics and 'success' of such projects. The responsiveness of researchers' specific contexts greatly matters to the room they have and take to involve farmers in their research.
Despite the widely accepted importance of the institutional context to understand the unfolding of farmer participatory research projects, still surprisingly little research has actually looked into its role in greater detail. By studying how a set of farmer participatory principles and methods were applied by researchers/advisers operating under different institutional conditions, this paper aims to fill this gap in literature. More specifically, it seeks to find out what institutional factors govern the researchers/advisers' behaviour and how these – indirectly – affect the unfolding of farmer participatory research projects.
This paper draws on a comparative analysis of four pilots that are part of the PURE-project's work package on 'co-innovation' (WP13), which is based on a farmer participatory research model. The four pilots took place in Denmark, France, Germany and the Netherlands, involved different national researcher/adviser-teams, farmer groups and focused on promoting IPM in different crops and farming systems. Although the pilots were part of the same project and had been guided by the authors of this paper with similar concepts and approaches, they showed their own dynamics, problems and successes. This makes them interesting cases to study the role of the institutional context. Each pilot's key events, dynamics and institutional context were reconstructed based on project reports, pilot team members' self-reflection documents and purposefully designed video meetings. Additional in-depth interviews were carried out with all members of the national researcher/adviser pilot teams in the final year of the project.
Based on a qualitative comparative analysis, this paper identifies major institutional factors and illustrates their influence on the unfolding of the co-innovation approach in the four cases, distinguishing between the personal, pilot team, work package, project, organisational and country AKIS level. More knowledge about the institutional factors and their specific effects is theoretically relevant for our understanding of complex farmer participatory research processes and practically salient to promote successful approaches in different innovation contexts.

EXPERIENCES FROM THE PILOTS – PRESENTATION OF THE VIDEO MATERIAL

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In this presentation, a few short videos are presented which describe successes and challenges regarding co-innovation of IPM efforts carried out in four pilots in The Netherlands, France, Germany and Denmark.

Due to the time constraints, only short parts of the videos can be presented. All the videos in full length will after the congress be available at the PURE website, http://www.pure-ipm.eu/

MANDATORY INTEGRATED PEST MANAGEMENT IN THE EUROPEAN UNION: EXPERIMENTAL INSIGHTS ON CONSUMERS' REACTIONS

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An experiment was conducted to analyse consumers' reaction to the transition towards Integrated Pest Management (IPM) as the standard in European farming. Preferences for fresh tomatoes produced by three different production systems of 189 French consumers were analysed: IPM, conventional and organic. Results indicate the existence of strong substitution opportunities between IPM and organic tomatoes. IPM sales will benefit from the withdrawal of conventional produces from the market only if there is a significant reduction in the price of IPM compared to organic and/or an important increase in the shelf space dedicated to IPM. Raising awareness on the impact of consumption choices on future prices of the produces has only a limited impact in this context. While information on IPM guidelines increases IPM products purchases, providing extra information on residue levels in IPM tomatoes has no further impact on consumers' choices.

IPM IN CORPORATE SUSTAINABILITY INITIATIVES: WHAT DO SYSCO, MCDONALD'S, WHOLE FOODS MARKET AND WALMART HAVE TO DO WITH IPM?

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IPM has earned a key role in corporate sustainability initiatives, including in major corporate initiatives by several US-based food giants. The IPM Institute is an independent non-profit organization working to leverage the power of the marketplace to improve health, environment and economics in agriculture and communities through IPM and other best practices. Since its founding in 1998, he Institute has partnered with food companies and others to create performance measurement and recognition systems incorporating IPM. With Sysco, a food service distributor with $45 billion in annual sales, and its processed fruit and vegetable suppliers, we have documented IPM and other best practices on more than 400,000 hectares worldwide. With McDonald's, ConAgra Lamb Weston, McCain's, Simplot, Cavendish, Heinz and Basic American Foods, the National Potato Council, the Canadian Horticultural Council and technology company FoodLogiQ, we have developed a new on-line facility for potato growers to assess, track and report IPM and other sustainability practices in potatoes grown in the US and Canada. This year, Whole Foods Market recently launched its Responsibly Grown rating system for fresh produce and flowers, where we incorporated several IPM elements into a comprehensive set of requirements for good, better and best ratings which are displayed on store shelves. Walmart has demonstrated the potential to greatly reduce pesticide use in distribution facilities by careful assessment of pest pressure, exclusion and sanitation. These programs are incorporating systems which encourage and document IPM and other best practice adoption, and also measure and report performance metrics including pesticide use and risk reduction. Food Alliance, Rainforest Alliance, the Forest Stewardship Council, Eco Apple, US Green Buildings Council LEED, Green Shield Certified and others are expanding opportunities for IPM users in agriculture and communities to earn recognition and market incentives for adopting and improving IPM. Currently, more than 16 million hectares are involved in these programs which include IPM as a required element in the US, and more than 152 million hectares worldwide.

NEW CHALLENGES FOR IPM RESEARCH IN HORTICULTURE

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In current IPM research, including PURE, the main targets are development of knowledge and tools for integrated pest/disease control and reduction of the environmental impact of chemical pesticides. Up to now the demands and ambitions of value chain partners and producers played a minor role in the planning of IPM research. As a result the implementation of IPM depends on technology push rather than on demand pull. From the farmers' and economic point of view it seems worthwhile to take the value chain perspective as a new challenge for IPM in horticulture.

The objective of our research within PURE was valorisation of IPM knowledge and technology in the market. In other words: to make application of IPM attractive for growers and IPM grown horticultural products attractive for retailers and wholesalers. As horticultural economists we had the task to draw attention for market pull innovation and, by doing so, promote the implementation of IPM in practice.

Our work was embedded in ex-ante and ex-post assessments of innovative IPM systems in PURE. The main elements of our methodology were exploratory surveys with value chain partners in Spain, Italy, France and the Netherlands and analyses of export statistics (volumes, values and prices over the period 2000–2013) of Eurostat. The value chain partners visited were: input suppliers, growers and trade companies in Spain, Italy and the Netherlands. The crops and products studied were: tomatoes, sweet peppers, cucumbers, apples and pears.

During the exploratory surveys in Spain and Italy the growers and trade companies collectively condemned the extreme pesticide residue requirements of German retail companies. Triggered by these complaints we compared the product prices for exports from Italy, Spain, France, Belgium and the Netherlands to Germany with the product prices for exports from Italy, Spain, France, Belgium and the Netherlands to other countries. The comparison showed considerable price premiums for exports to Germany. The price premiums were bigger for products with much product differentiation (tomatoes, sweet peppers and apples) than for products with little product differentiation (cucumbers and pears).

From these results we concluded that the top-segment in the market (German retailers) is willing to pay premium prices for top-quality horticultural products. Top-quality includes attributes like improved cultivars, good taste, nice colour, attractive packing and low pesticide residue. Application of IPM tools and knowledge is a key to achieving low residue levels. Consequently the new challenge for IPM research in horticulture is participating in product development together with plant breeders, agronomists and trade companies and retailers. This participation in product development will help growers and traders in fetching higher product prices and, simultaneously, making them enthusiastic for the implementation of IPM tools and knowledge in practice.

AMPELOMYCES QUISQUALIS FOR CONTROL OF POWDERY MILDEW

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Ampelomyces quisqualis is an intracellular mycoparasite of powdery mildew and the active ingredient of the oldest biofungicide but the new isolated *A. quisqualis* strain ITA3 showed an higher efficacy in controlling powdery mildews. Research is currently underway towards to develop a suitable conidial formulation strategies for use as an effective biocontrol agent against powdery mildew in agronomical field applications. The development of production and formulation processes for biocontrol fungi has primarily focused on reducing costs by maximizing the yield of infective propagules, increasing storage stability, and improving product form for an ease application. To enable commercial production of the conidia of ITA3, the medium composition and culture conditions were optimized in the current study in order to obtain maximum biomass during growth phase and maximum conidia yield during subsequent conidiation phase. We also considered stability as a dry preparation and biocontrol efficacy of the conidial formulation. Many statistical experimental design methods have been employed in bioprocess optimization. Among them, response surface methodology (RSM) is the one suitable method for identifying the effect of individual variables and for seeking the optimum conditions for a multivariable system efficiently. Here, the RSM approach was adopted to locate optimum levels of substrate concentration. In the present study, yield of the strain ITA3 vary much depending on the substrates, cultivation methods and conditions. Cultivating conditions such as higher surface aeration (220 rpm) and lower initial pH value (pH 6.5) were demonstrated to produce good yields of conidia in this fungus. The optimized jaggery broth medium has resulted in significant enhancement in the productivity of the biomass and conidial yield. An increase of 23.2 – fold in biomass and 1.4×10^6 – fold in conidial yield were obtained with optimized jaggery broth at a reduction of 43% in time in comparison to the base jaggery broth. Other aspects of this work regarded the scale-up of *A. quisqualis* inoculums for biocontrol purposes which was one of the crucial steps towards its commercialization and practical use in plant protection. In our experiments conidia of ITA3 were formulated and then sprayed on powdery mildew colonies. Solid based silicagel formulation with 25 ml of conidial suspensions (10^7 conidia g ml^{-1}) and 50 grams of silicagel powder gave the best powdery mildew control. The high conidial yield and the good biocontrol results achieved in the present study with silicagel formulated conidia seems to be economically sustainable for commercial production of *A. quisqualis.*

TRICHODERMA ATROVIRIDE FOR CONTROL SOIL-BORNE PATHOGENS

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Trichoderma atroviride SC1 has biocontrol properties against several soil-borne plant pathogens. However its persistence in soils is often very short, thus the efficacy in reducing pathogen's inoculum can be rather limited. This is particularly true for soil-borne pathogens as *Armillaria mellea*, which can survive several years in root residues in soil. Bark mulch is commonly used to control weeds and preserve soil fertility. However the use of *Armillaria*-infected coniferous bark can led to the spread of *Armillaria* root rot in orchards. We demonstrated that coniferous bark can be used as a carrier to distribute and maintain high levels of *T. atroviride* SC1 inoculum in soil. The different types of bark examined did not have any differential effects on the level of biocontrol activity against *Armillaria gallica*. *T. atroviride* SC1 can persist and grow on bark for a long period after treatment (up to 16 weeks). The incidence of disease on plants that were mulched with bark pre-inoculated with SC1 and then infected with *A. gallica* was significantly lower than that observed on the untreated control (25 and 70%, respectively).

THE NEW METHOD OF INSECT MATING DISRUPTION BY VIBRATIONAL NOISE

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Scaphoideus titanus is a leafhopper insect, vector of the grapevine FD phytoplasma. Since FD is recognized as a quarantine disease, compulsory control measures include the large-scale treatments of vineyards with insecticides, including neurotoxic compounds and chitin synthesis inhibitors. The concerns about detrimental effects of pesticides on biodiversity and human health are leading to an increasingly restricted use of chemicals in agriculture. One of the main challenge in increasing the safety of the global food production is to identify appropriate alternative approaches for
the numerous insect pests that do not rely on chemical communication. Since the first successful field trial, pheromone based mating disruption enabled sustainable insect control, which resulted in reduced levels of pesticide use. However, in *S. titanus* the mating behaviour is driven by substrate-borne signals while pheromones are absent. In fact, vibrational signals are crucial for the species mating success in that a male and a female establish a stereotyped vibrational duet that enables partner recognition and localization. In the present contribution, we show that effective mating disruption based on substrate-borne vibrational signals can be achieved in the field. When the device which transmitted disruptive vibrational signals to grapevine plants through a supporting wire, mating frequency of the leafhopper pest dropped to less than 10% in a mature vineyard. The underlying mechanism of this environmentally friendly pest-control tactic is a masking of the vibrational signals emitted by *S. titanus* during pair formation. Because vibrational communication is widespread in insects, mating disruption using substrate vibrations can transform many open field and greenhouse based farming systems.

INTEGRATED MANAGEMENT OF THE INVASIVE TOMATO LEAFMINER *TUTA ABSOLUTA* IN FLANDERS (BELGIUM)

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Since its first detection in Flanders (Belgium) in 2009, the South American tomato leafminer *Tuta absoluta* is now frequently encountered in tomato greenhouses in this region. In the framework of the European Directive 2009/128/EC on the sustainable use of pesticides, an integrated control strategy against this pest in protected areas is being developed.

It was assumed that the low temperatures commonly associated with Belgian winters would prevent the exotic species from successful overwintering. Experiments on cold-hardiness, however, demonstrated that the adults and pupae of this leafminer can overwinter in empty but frost-free greenhouses for at least two weeks. Therefore there should be aimed for an as low as possible population level of *T. absoluta* towards the end of the production cycle. This minimizes the number of overwintering adults and pupae, thus allowing the new crop to start in a clean environment which is the first step in an integrated pest management approach.

Currently *Macrolophus pygmaeus* is the most used commercial natural enemy against *T. absoluta*. Population buildup of this predatory bug is slow, making it difficult to control *T. absoluta* at the beginning of the production cycle or when pest levels are high. The population growth and distribution of *M. pygmaeus* in the greenhouse should be optimized by releasing the predator as soon as possible after planting in combination with the provision of food supplements. Laboratory experiments demonstrated that the predatory bug prefers the eggs of *T. absoluta* and preys only to a limited extent on the larvae.

To complement the limited control potential of *M. pygmaeus* towards *T. absoluta* larvae, the efficacy of three commercially available entomopathogenic nematodes (EPN) *Steinernema carpocapsae*, *S. feltiae* and *Heterorhabditis bacteriophora* was tested against the four larval stages of *T. absoluta*. Control of the larger larval instars L3 and L4 was most successful, resulting in 71.8–97.4% mortality. The efficacy of the selected EPN was tested at 18°C and 25°C. At both temperatures, *S. feltiae* was most effective, killing 100% of the larvae after three days. The above findings show that EPN might be implemented in an IPM strategy to control this pest but appropriate spray application techniques need to be developed to obtain an optimal deposition of EPN infective juveniles on tomato leaves.

THE EFFECT OF β-AMINOBUTYRIC ACID (BABA) ON CROP PLANT CAPABILITY TO MANAGE HERBIVOROUS PEST ATTACK

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According to the Directive 2009/128/EC on integrated pest management (IPM), non-chemical methods of pest control should be used as an alternative to chemical plant protection. Recently, more and more chemical elicitors are studied and recommended to modify plant capability (either hormonal signalling pathways or metabolic events) to effectively alleviate negative effects of biotic/abiotic stresses.

This review presents the recent findings on the effectiveness of plant priming by BABA (non-protein amino acid) against different taxa of phytophagous pests, and aims to provide a better insight into the potential of BABA-induced plant defence as an alternative or supplementary method for pest control.

Our updated review shows the following:

(1) BABA-induced plant resistance against herbivorous pests representing various life-styles (aphids, psyllids, caterpillars, root-knot nematodes) has been demonstrated in 21 plant species belonging to 7 botanical families;

(2) The evaluation of BABA efficiency in plant protection against pests has mostly been carried out by using young plants or seedlings. The preferred method of BABA application was 'soil drench' at 25 mM or 50 mM concentration;

(3) Generally, BABA applied as 'soil drench' at 25 mM or 50 mM concentration has no impact on plant fitness (e.g. plant growth, fresh and dry matter accumulation etc.);

(4) BABA treatment at 25 mM – 50 mM concentration enhances protection of tic bean, pea, broad bean, runner bean, red clover and alfalfa against the pea aphid (*Acyrthosiphon pisum*); Arabidopsis against the cabbage aphid (*Brevicoryne brassicae*), the cabbage looper (*Trichoplusia ni*) and the diamondback moth (*Plutella xylostella*); calabresce, and also of cabbage, spring cabbage, salad rape, black and white mustard against *B. brassicae*, the green peach aphid (syn. the peach-potato aphid) (*Myzus persicae*), *T. ni* and *P. xylostella*; wheat against the grain aphid (*Sitobion avenae*); soybean against the soybean aphid (*Aphis glycines* Matsumura) and citrus against the Asian citrus psyllid (*Diaphorina citri*).

(5) The most likely, decrease in pest performance, measured as r_m, adult survival or mortality, female fecundity etc., was casued by BABA-induced change in quality of the treated host-plants;

(6) In two cases, also negative impact of the prey fed on BABA treated plants on its natural enemies (parazytoid; predator) was documented.

IN VITRO INHIBITION BY NATURAL WHEAT CHEMICALS AND IDENTIFICATION OF THEIR BIOCHEMICAL TARGETS

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Fusarium head blight (FHB) is a severe disease in wheat caused by mainly *F. graminearum* and *F. culmorum*. FHB results in significant yield losses and in accumulation of the trichothecene mycotoxins in grain. Susceptibility to Fusarium and mycotoxin accumulation in grain is cultivar dependent, *e.g.* Sumai-3 wheat cultivar exhibits high FHB resistance and low accumulation of trichothecenes in grain. In order to reduce the use of fungicides, various plant secondary metabolites have been studied for their ability to inhibit trichothecene biosynthesis, e.g. ferulic acid and 4-acetylbenzoxazolin-2-one.

Several secondary metabolites naturally occurring in wheat (including benzoxazinoids, phenolic acids, cinnamic acids, and flavonoids) were tested for their inhibitory activity against trichothecene production in liquid cultures with a *F. graminearum* lineage producing the trichothecene B, 15-ADON. The benzoxazinoid 2,4-dihydroxy-7-methoxy-1,4-benzoxazin-3-one (DIMBOA) completely inhibited toxin production, while the structurally similar 2,4-dihydroxy-1,4-benzoxazin-3-one (DIBOA) and 2-hydroxy-7-methoxy-1,4-benzoxazin-3-one (HMBOA), lacking of 7-methoxy and 2-hydroxy group, respectively, did not possess any inhibitory activity. Benzoxazinoids benzoxazolin-2-one (BOA) and 6-methoxy-benzoxazolin-2-one (MBOA) and the flavonoid homoorientin exhibited moderate inhibitory activity. *trans*-ferulic acid and *trans*-p-coumaric acid, stimulated toxin production several fold compared to controls.

Employing *tri6* and *tri5* gene expression and TRI5 and TRI4 trichothecene protein assays, we were able to identify targets of the trichothecene biosynthesis pathway. DIMBOA suppressed *tri6* gene expression and partially inhibited TRI4 protein activity, while BOA only temporarily suppressed *tri5* gene expression. Initial experiments for homoorientin suggested that TRI5 was the target for the flavonoid. Previous results by other authors (Ponts et al. (2011), *Phytopathol.*, 101, 929–934) revealed that ferulic acid enhances toxin production by upregulating expression of *tri5*.

To our knowledge this is the first time that the benzoxazinoids DIMBOA, DIBOA, MBOA and BOA have been tested for their effects on trichothecene production.

Our results indicate that DIMBOA plays an important role in the suppression of the production and accumulation of toxic trichothecenes in wheat grain. Further studies of these wheat metabolites are highly desired to test the effect of these wheat secondary metabolites with other lineages of *F. graminearum*.

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OVERVIEW OF EU-FUNDED PROJECT BIOCOMES

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The EU emphasizes the role of integrated pest management as an important approach to reduce dependency on pesticides use (Directive 2009/128/EC). Biological control of pests and diseases can be a very effective, sustainable and environmentally friendly strategy for crop and forest protection as part of integrated pest management (IPM) practices. The availability of sufficient biological control products is important for an effective IPM strategy. Unfortunately, biological control alternatives against a range of important pests and pathogens – causing high economic losses to agriculture and forestry – are not or not sufficiently available at this moment. The objective of the EU project BIOCOMES is to develop 11 new biological control agents (BCAs) and 2 production technologies for key markets in European agriculture and forestry. BCAs were identified through market analysis by six manufactures of biological control products. BCAs will primarily be for use in open field crops of vegetables (3), of which 2 are also for use in protected crops, arable crops (3), fruit crops (3), and three different types of forests (2). Primary targeted pests are: gypsy moth (*Lymantria dispar*), pine weevil (*Hylobius abietis*), tomato leaf miner (*Tuta absoluta*), white flies, aphids of fruit tree crops and *Mamestra brassicae*. Primary targeted pathogens are: damping-off diseases in forest nurseries, soilborne pathogens of oilseed rape and cereals, brown rot (*Monilinia* spp.) of stone fruit, and powdery mildew of cereals (*Blumeria graminis*). The economic sustainability during the entire development process will be assessed by the responsible industrial partners. The environmental sustainability will be quantified for each BCA by means of the Sustainable Process Index method. The entire developmental process for each of the 11 BCA products is guided by a consultancy partner specialized and leading in (bio) pesticide registration including risk assessments for European (bio) pesticide industries.

PRESENTATION OF THE ROLE AND MISSION OF THE IOBC©: INTERNATIONAL ORGANIZATION FOR BIOLOGICAL AND INTEGRATED CONTROL AND ITS COMMISSION «GUIDELINES FOR INTEGRATED PRODUCTION»

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IOBC is a non-profit, scientific organization of individual and institutional members working with biological control, Integrated Pest Management (IPM) and Integrated Production (IP), acting since 1956. Its mission is to provide independent, professional advice on biological control, IPM and IP to policy makers, governments, advisory services and farmers; as well as to raise public awareness of their economic and social importance.
Briefly, IP is a concept of sustainable agriculture based on the use of natural resources and regulating mechanisms to replace potentially polluting inputs. The agronomic preventive measures and biological/physical/chemical methods are carefully selected and balanced to safeguard the protection of the environment and the health of workers and consumers. Emphasis is placed on a holistic systems approach involving the entire farm as the basic unit, on the central role of agro-ecosystems, on balanced nutrient cycles, and on the welfare of animals in animal husbandry. IPM (Integrated Pest Management) is the part of IP focusing on pest and disease management.
The objectives of the IOBC Commission «Guidelines for Integrated Production» are to establish the IP framework and guidelines from the expertise of the IOBC working groups and to support the implementation of IP/IPM into practice.
Website: http://iobc-wprs.org

SCALING UP IPM

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IPM systems can be viewed at multiple scales, from field, to farm, to watershed and ecoregion, and from the perspective of the individual decision maker, through a series of social ecological tiers that ultimately encompass the system. Programs that advance IPM adoption must be scaleable, and master resource, process, and conceptual challenges in order to sustainably embed IPM concepts and practices within farming systems. I will outline a series of informative studies from the work of the IPPC in the USA, and in West Africa, and explore successes, failures and challenges in the pursuit of system-level adoption of IPM. In the USA, participatory, outcomes-based education programs, which incorporate the cooperative development of decision support tools with stakeholders, have enabled IPM adoption and pesticide risk reduction at the watershed scale. These methods respond to monitoring of adverse, system-level pesticide impacts by providing a vehicle for joint learning and innovation, supported by feedback from monitoring data. Examples include pome fruit IPM, and the reduction of organophosphate pesticide use to protect endangered Salmonidae, and the use of novel pesticide risk assessment tools to guide pesticide selection that is protective for pollinators. Well-designed, short-term, education programs can tune IPM in systems that are already well supported by regulation, access to extension education, and responsive resource channels. The US system is also open to legislative refinements that require IPM to be adopted, and which provide an environment that is conducive to voluntary measures by farmers, who participate in pesticide stewardship partnerships. In West Africa, we face a far more vulnerable system, with limited regulatory capacity, limited access to education, and scarce resources. Regional portrayals of pesticide risk in the Niger and Senegal River Basins are helping to focus programs on the greatest threats to human health, the environment and productivity. The efficiency and effectiveness of regulation is being explored with regional and national regulatory authorities, and outcome-based extension education programs are reducing pesticide risks locally. Our challenge however, is scaling up education programs to reach a significant proportion of farmers across a vast area. New technologies and information pathways will help, but our work suggests that there is no substitute, in any system, for effective, scientifically based, participatory extension programs.

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).

Fig. 1. Apple orchard with rain cover under hail net protection (Ctifl – Lanxade)

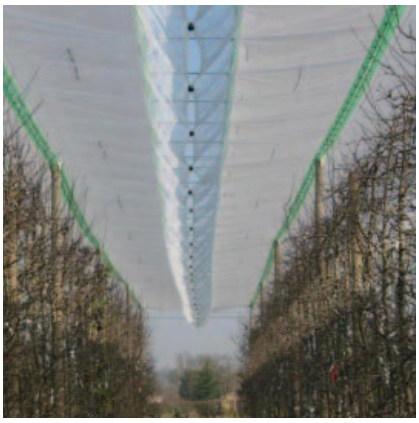

Fig. 2. Rain cover and hail net may be combined above the apple trees (Ctifl – Lanxade)

Fig. 3. Newly planted apple trees covered by several plastic strips fixed on the hail nets, and moving with the wind (Ctifl - Lanxade)

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.

IPM IN SOUTHERN EUROPEAN GREENHOUSES: STRENGTHS AND WEAKNESSES

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This work analyzes information gathered from two surveys carried out in 2011 and 2014 within the framework of the European PURE program subsidized by FP7 KBBE funds.

Various stakeholders, i.e., suppliers, advisers, growers, cooperative managers, from Spain, France and Italy have been interviewed in order to give their input on the main opportunities and setbacks of Integrated Pest Management in greenhouse horticulture production according to their relevant technical and socio-economic surroundings.

The information gathered during the first survey showed really contrasting situations among the selected regions regarding both the greenhouse production system and the IPM strategies. Furthermore, this study highlighted a strong correlation between the main pests and diseases observed locally coupled with specific strategy management and environmental conditions.

By the same token, real IPM management promoting biological control appeared to be highly related to differing local factors such as greenhouse technical level, growth and rotation calendars, availability of biological control agents as well as target markets.

The second survey showed that the use of IPM is spreading in Southern European greenhouses and has extended to become the general rule for tomato production. Nevertheless, many issues remain in specific situations namely fungi diseases and soil-born pathogens.

GREENHOUSE CLIMATE INVESTIGATIONS FOR ADVANCED IPM MANAGEMENT

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Gaining knowledge's on the biophysics mechanisms underlying protected climate setting and more particularly the conditions prevailing at leaf level is crucial because air humidity considerably increases close to leaf surface and can promote the damages caused by pests (fungi and insects). It is interesting to control the distributed climate in the ecological niche sheltering the pests, diseases and BCAs threatening the crops and thus to implement more efficiently the various alternative methods (climate, physical, etc.) to the use of chemical products.

The main research activity for this work concerns the Computer Fluid Dynamics (CFD) based modeling and characterization of the distributed climate in the greenhouse.

We have focused on a crucial issue concerning the novel numerical coupling of radiative and convective transfers within the CFD software, together with the coupling between crop activity and the distributed microclimate. Both improvements have more precisely allowed (i) studying pest occurrence distribution with respect to climate patterns and (ii) modeling the microclimate in the leaf boundary layer in the ecological niche of pests. (iii) evaluating the substitute materials to leaf domatia presents on Viburnum tinus to identify which material can "mimic" the climatic characteristic of leaf domatia to ensure the stability of the beneficial insects. (iv) characterizing and modeling of microclimate heterogeneity at the plant level, in relation to the repartition of biocontrol agents (*Neoseiulus cucumeris* and *Amblyseius swirskii*) used to control thrips on greenhouse crops.

The results evidenced that (i) the microclimate (air temperature and humidity) at leaf and plant levels is very heterogeneous. Mapping together climate conditions at this level and the distribution of beneficial insects and pests can provide new information about their climate preferences and suggest control strategies allowing for a wiser control of greenhouse pest infestations.

(ii) The observed discontinuities between the climate in the leaf boundary layer and the ambient air prove that for improving the crop pest's control, the boundary layer micro climate conditions must be directly targeted rather than controlling the ambient air climate. More specifically, air humidity, the crucial parameter controlling pest activity, must not be considered in the air at the center of the greenhouse near the growing point but in the leaf boundary layer.

The resulting model could be used to test a climate control strategies to fight against pests by modifying the temperature and the humidity by deploying techniques and strategies, such as localized heating or ventilation aiming at directly controlling the microclimate inside the boundary layer of leaves to make it unfavorable for pests. It may also be used to identify the risk areas and to save time and money for growers by releasing biocontrol agents in small areas surrounding these risk zones.

INTEGRATED PEST MANAGEMENT BASED IN THE USE OF MIRIDS IN GREENHOUSE TOMATOES OF SOUTHERN SPAIN

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During the last decade pest management in protected tomato crops in southern Spain has evolved from a purely chemical management to a strategy based on biological control of pests where pesticides against pests are rarely used. The appearance of the invasive pest *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in 2006 in Spain, prompted to develop strategies to control this threatening tomato pest, based on the use of mirid predators (Hemiptera: Miridae). The use of the predatory mirid bug *Nesidiocoris tenuis* Reuter (Hemiptera: Miridae) resulted very effective in controlling tomato key pests: *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) and *T. absoluta*. In addition, due to the high polyphagy of this predator, most tomato pests are under control, with the exception of *Aculops lycopersici* (Masse) (Acari: Eriophydae) which escapes to the control of this predator. The success of the use of *N. tenuis* has minimized the use of pesticides in tomato and the specific treatments conducted are currently mainly targeted to control *A. lycopersici* with selective acaricides.

INCREASE OF BIODIVERSITY OF THE FIRST TROPHIC LEVEL AS A NEW IPM TOOL

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Research has documented the importance of tri-trophic interactions in IPM systems but rarely from an "arthropod" point of view. The employment of biocontrol plants has proven to be efficient in IPM. These are intentionally added to a crop system in order to enhance crop productivity through predator attraction and/or pest regulation. Understanding the effects of particular plant structures on tri-trophic interactions appears essential to improve the efficiency of biocontrol systems. The present paper describes the results of experiments testing two species of biocontrol plants as potential banker plants in tomato crops using the predatory mirid bug *Macrolophus pygmaeus* to control whitefly pest *Trialeurodes vaporariorum* in IPM greenhouses in South-Eastern France. Basil (*Ocimum basilicum*) is an efficient intercrop in pest management known for its repellence effect. However its function as banker plant to help the presence of the predatory mirid bug *Macrolophus pygmaeus* for biological control of whiteflies remains unstudied. In this context we investigated the effect of basil as banker plant in an IPM greenhouse to enhance the presence of the predatory bug *M. pygmaeus* in tomato crop system. In a 6 week experiment, we evaluated simultaneously three plant combinations composed by basil and/or tomato in dicultures (two-crop mixtures) or monoculture of the same species. We compared incidence of the pest *T. vaporariorum* (whitefly) and the predatory bug on the yield of tomato plants. We counted the number of individuals of *M. pygmaeus* and *T. vaporariorum* on basil and tomato. At the end of the experiment, a destructive sampling showed that pests were significantly less numerous in the diculture or when basil was present. However, number of predators, crop yield and leaf health were not statistically different between plant combinations. Basil had an effect on whitefly control as there was a good predation success but with the present experiment we could not define basil as an efficient banker plant.
Dittrichia viscosa, which is a Mediterranean entomophilous plant, is known to enhance beneficial arthropod populations. Our second study assessed the population development of *M. pygmaeus* and *T. vaporariorum* on *D. viscosa* and on tomato. The results were negative in that the predators did not install on *D. viscosa*, and the combination of *D. viscosa* + tomato induced an increase of the pest population. On *D. viscosa* grown with tomato, 2246 individuals of *T. vaporariorum* (adults and larvae) were identified after eight weeks, compared to 241 on the treatment with only tomato plants and 34 with only *D. viscosa*. Although *D. viscosa* is efficient for other species combinations, it is not suitable for the protection of tomatoes against *T. vaporariorum* in greenhouse, and does not act as banker plant for *M. pygmaeus*.

APPLICATION OF PHEROMONE-BASED CONTROL OF *TUTA ABSOLUTA* IN GREENHOUSE TOMATO IPM IN CAMPANIA, SOUTHERN ITALY

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Greenhouse tomato in Campania is cultivated mainly during the spring-autumn season when different pests, including the borer *Tuta absoluta*, the whiteflies *Trialeurodes vaporariorum* and *Bemisia tabaci*, and the thrips *Frankliniella occidentalis*, can injury the crops simultaneously. While *T. absoluta* and whiteflies can be controlled effectively by inoculations of biocontrol agents, the most effective of which is the predator *Nesidiocoris tenuis*, and natural populations of parasitoids and predators, the efficacy of *F. occidentalis* biological control on tomato remains elusive. Farmers use frequent insecticide sprayings to control thrips, so disrupting the biological control of other pests, with the consequence that additional insecticides must be applied to control borers and whiteflies. In a three-years field trial (2012–2014) we used the false trail following techniques (FT) to control *T. absoluta* in combination with a) insecticides applied specifically to control thrips or b) biocontrol agents. We found that: *T. absoluta* male ability to respond to calling females is inhibited by the pheromone dispensers distributed within the greenhouses; FT in combination with *Bacillus thuringiensis* and chemical control of thrips is effective in reducing the number of chemical insecticide applications by 40% compared with the farmer chemical control strategy and preventing yield losses due to *T. absoluta*; FT in combination with the predator *N. tenuis* and other biocontrol agents is effective in preventing yield losses due to *T. absoluta* as the farmer chemical control strategy; fruit injury by thrips (direct damage) and whiteflies (indirect damage) did not differ between the FT-based IPM and the farmer chemical control strategy. Our data suggest the use of FT as a mean to improve Integrated Pest Management and sustainability of greenhouse tomato production at least in Southern Italy.

TRICHOGRAMMA ACHAEAE AS AN IPM TOOL IN TOMATO GREENHOUSES

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Trichogramma wasps are endoparasitoids of Lepidoptera eggs. They are used as biological control agents against Lepidoptera pests.
The species Trichogramma achaeae is used against the invasive Tomato leafminer Tuta absoluta.
As part of the European project PURE, on-farm trials of integrated pest management were conducted in the south of France, based on the use of two BCA : Trichogramma achaeae and Macrolophus pygmaeus.
These on-farm trials have shown the value and effectiveness of the use of Trichogramma achaeae as an IPM tool against Tuta absoluta.

ARTEMIA AS SUPPLEMENTARY FOOD FOR THE PREDATORY MIRID *NESIDIOCORIS TENUIS*: IMPLICATIONS FOR BIOLOGICAL CONTROL IN TOMATO CROPS

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Nesidiocoris tenuis (Reuter) (Hemiptera: Miridae) is a zoophytophagous predator widely used in integrated pest management programs in both, greenhouse and open-field, tomato crops.
Mass rearing of *N. tenuis* is greatly dependent on *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae) eggs as food source. Moreover, the addition of this factitious prey after the inoculative releases of *N. tenuis* under field conditions is recommended to facilitate establishment of this mirid. However, *E. kuehniella* eggs are expensive and availability is limited. Some alternative foods as decapsulated *Artemia* cysts have given very good results in terms of biological development and reproduction of other Hemiptera predators. In this work, our objective was to evaluate the development of the juvenile stages of *N. tenuis* and the fecundity of females emerged from the assay of development, when subjected to a strict diet of decapsulated *Artemia* cysts, on tomato leaf in laboratory conditions. Moreover, we assessed the effectiveness of this alternative food (factitious prey) to improve the establishment of *N. tenuis* in a greenhouse tomato crop conditions. Our results may have practical implications of interest in mass rearing systems of *N. tenuis* and its management in greenhouse and field crops as a part of biological control programs.

INNOVATIVE DECISION SUPPORT SYSTEM FOR IPM IN GREENHOUSES

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Since biological control is a real part of IPM strategy, an important shift in attitude is needed on behalf of the growers to monitor the culture and the pest and natural enemy communities. As a matter of fact, contrary to conventional chemical pesticides, biological control tools are much more targeted, although they induce a delayed effect and are more dependent on biotic and abiotic factors. In addition, the main objective is not to eradicate pests but to maintain an accurate balance between them and the natural enemies.
These changes require, *de facto*, accurate monitoring of the various biotic elements in the cropping system as well as new tools to analyze the huge amount of data generated.
To undertake this, our laboratory has designed a large database called S@M, i.e. “Sophia Data Market” which includes a wide selection of tools aiming at providing effective help for growers to take relevant decisions.
This intelligent system encompasses: i) training tools to identify pests and natural enemies, ii) monitoring tools adapted to each pest, natural enemy and crop, iii) forecasting models for the main pests and diseases, iv) traceability tools for IPM management.
The system has been created to allow the grower to record the sanitary status of crop straightaway in the greenhouse on a tablet, to obtain real time risk analyses and a pool of information regarding potential decisions.

TRAINING EXPERIENCES FOR TOMATO GREENHOUSE FARMERS

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The European Directive 128/2009 for the sustainable use of pesticides pleads for the reduction of use and dependence on pesticides of the European agricultural production. It fosters the use of integrated pest management (IPM) strategies and supports the training of pesticides users as a key element for the success in the application of this Directive. In this context, the PURE European R&D program has been developed and devoted to the pesticide's use and risk reduction of key farming systems in Europe. Within this project, the Valencian Institute of Agricultural Research (IVIA, Spain) has participated in the development of IPM solutions for protected crops, particularly in the greenhouse tomato system in the Mediterranean basin. The appearance of the invasive pest *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in 2006 in Spain, prompted to develop strategies to control this threatening tomato pest, based on the use of mirid predators (Hemiptera: Miridae). The use of the predatory mirid bug *Nesidiocoris tenuis* Reuter (Hemiptera: Miridae) has resulted extremely effective in controlling tomato key pests: *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) and T. *absoluta*. Therefore, the objective of this work has been twofold: first, to train farmers in the use of *N. tenuis* as key biological control agent for greenhouse tomato production; and second to accompany them in the application of this new control strategy. The first objective was accomplished with several training days, in which participants (more than 50 in 3 sessions) learn the basics of the *N. tenuis* bioecology, as well as for the main tomato pests (*T. absoluta, B. tabaci*) both in laboratory with the use of binoculars and in the field with magnifying lens. We also presented how to set up and implement this strategy in practice in a real tomato crop in a greenhouse especially grown for this purpose where participant learned the traps they need, the monitoring frequency, the pests to monitor, etc.) The second objective consisted in giving weekly support to several growers of protected tomato producers in Valencia. These growers served as an example. The good results obtained (pest control, ease of use and much cheaper strategy) fostered the acceptance and spread out of the release of *N tenuis* strategy for IPM protected tomato. In addition, we participated in several seminars and workshops in which we presented the practical solution developed as well as the results of our on-station trials.

"THE HEALTHY GREENHOUSE": HEALTHY FOR PLANTS, MAN, AND THE ENVIRONMENT

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Conditioned crop production as in greenhouses form an ideal system for the most innovative IPM-approach. However as the sizes of greenhouses increase, manual monitoring and taking appropriate measures are getting more difficult in practice, limiting the potential of using alternative control methods in time. The development, use and integration of early diagnostics and precise application technologies of (bio)pesticides, would facilitate large greenhouses being the most sustainable production system. And this has been established in the recently finished (2011–2014) INTERREG Program 'Healthy Greenhouse', supported by the EU and the Dutch and German provinces close to their joint border. About 10 research groups and 22 high-tech companies joint, to develop about 20 products and test them in one IPM cropping system 'Healthy Greenhouse' on two crops, tomato and potted plants.

'Healthy Greenhouse' comprises of 4 building blocks: healthy start, monitoring, taking appropriate measures, and a farmers dashboard for control.

Healthy start, a multiplex detection system (antibody- and DNA based Luminex equipment) was developed to certify plant material, topsoil/substrate, irrigation water and the environment for being free of pests.

For *Monitoring*, 2-steps methods have been developed. Macro-monitoring was performed with vision technologies (CF-camera or Multispectral Imaging Sensor) mounted on a cart running through the whole greenhouse, giving real time images and locations of plant parts showing stress. Those parts were inspected by human and if not clear, a second micro-method was used by sampling and testing on the occurrence of a pest with Luminex-multiplex .

Appropriate *Measures* were started with e.g. a combination of endophytes and predatory insects for synergistic pest control. If not fully successful crop adapted precision spraying was applied using the same carts as for monitoring in which the vision devices are coupled to robotised spraying equipment, only spraying the suspected area of the leaf or stem of tomato (vertical system) or cyclamen (horizontal system).

All data generated from the building blocks, come together in the *dashboard*: a SCOT database for data containment, data exchange. The dashboard shows notifications for the grower in a traffic light manner. The grower may see the hot spots of pests in his greenhouse, translate the data into action, and evaluate the efficacy of various measures.

This whole integrated 'Healthy Greenhouse' system has been built and demonstrated in the experimental greenhouse in Straelen, Germany, showing optimal IPM control in the two crops, with a reduction of 35–50% of the chemical pesticide use. The results of this just finished project will be presented (including a video of operations in the experimental greenhouse), showing state-of-the-art possibilities for sustainable crop protection in green houses in the 21st century.

INNOVATIVE SUSTAINABLE TOOLS FOR IPM OF TOMATO IN PROTECTED CULTURE

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Tomatoes are one of the most popular and widely grown vegetables in the world either in the field or under greenhouse conditions. In Europe, tomatoes are produced mainly under protected conditions by using an extremely intensive cultivation method, with yields that can reach 700 tonnes/ha. Despite the EU Directive (2009/128/EC) on sustainable use of pesticides, which promotes Integrated Pest Management (IPM) and the implementation of biological alternatives for pest control, the use of chemical pesticides is still very important for crop protection in greenhouse horticulture including tomato cultivation. *Trichoderma* spp. are widely studied fungi and among the most commonly used microbial biological control agents (MBCAs) in agriculture. They are considered as "generalist" MBCAs because are capable of controlling a large spectrum of taxonomically diverse pathogens by using a variety of mechanisms mediated and non-mediated by the plant. For instance, some strains are capable of systemically "prime" and/or activating plant defense responses. This is now considered a very significant mechanism of crop protection as compared to direct antagonism of the pathogen. Moreover, the list of positive effects of *Trichoderma* on plants includes improvement of growth, development, and yield. In the frame of the PURE project, the activity carried out in WP7 has demonstrated that not only some *Trichoderma* strains can be positively combined with other IPM applications, but also *Trichoderma*-produced bioactive compounds (i.e. enzymes and other proteins or secondary metabolites) can be used as an effective alternative to the living fungus. The application of selected bioactive compounds produced by MBCAs may represent an innovative IPM tool because: i) the constrains associated with the production, application and establishment of the living microbe may be overcome; ii) the efficacy of the treatment may be more precisely dependent on the dose of the active principle used; iii) some applications are more effective or possible, such as control of foliar pathogens, as many MBCAs are root-associated; iv) beneficial effects on the plant may be improved and more consistent; v) it is possible to develop highly active synergistic mixtures of bioactive compounds and the living MBCAs.

WINTER WHEAT BASED ROTATIONS – AGRONOMIC EVALUATION OF IPM STRATEGIES

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Six multiyear field experiments were conducted comparing the agronomic, economic and environmental performance of current practice and two IPM strategies (named intermediate and advanced IPM, respectively) in winter-wheat based crop rotations. In this presentation, the results of the agronomic performance are presented. The experiments were conducted in Denmark, France (2 locations), Germany, Poland and Scotland. The experiments in Denmark, Germany, Poland and Scotland were initiated as part of PURE and have only run for three years while the two French experiments were on-going experiments designed to study other aspects than IPM implementation. The four experiments in Denmark, Germany, Poland and Scotland were 3-year rotations including only the three strategies. The French experiments had more treatments and current practice and the two IPM strategies were chosen among the treatments. In one of the French experiment advanced IPM was a 'no pesticide' scenario while in the other one it was an 'organic' scenario. Except for the German trial, crop rotation was part of the IPM strategies. Decision on pesticide use varied between trials. In some trials Decision Support Systems were used while in others the same pesticides were used in the IPM strategies as for the current practice but at reduced doses. Advanced IPM typically included mechanical weeding and resistant varieties, variety mixtures, delayed sowing and other non-chemical tactics.

In general weeds, diseases and pests were well controlled with current practice and the intermediate IPM strategy while unsatisfactory control was observed with the advanced IPM strategy in some years at some locations. Winter wheat yields at intermediate IPM were comparable to and in some cases lower than those at current practice while yields at advanced IPM generally was lower than at current practice. Yield losses were highest in the two French trials where the advanced IPM received no pesticide applications. In some cases yield losses could be attributed to the applied IPM measures, e.g. delayed sowing, while in other cases it was caused by an insufficient pest control. Pesticide use was significantly reduced in both the intermediate and advanced IPM treatments compared to current practice. Lessons learnt from the experiments were that variety mixtures are a very effective tool for reducing the impact of disease pressure and thus fungicide use, that inter-row cultivation is very effective in winter oilseed rape while the performance of weed harrowing was variable. The study also showed that omitting the use of pesticides can result in pronounced yield losses in winter wheat but also revealed that there is considerable scope for reducing pesticide use in winter wheat by adopting IPM measures without significant yield penalties.

No significant long-term effects of the IPM strategies were observed but the experiments will continue for another 3 years where e.g. a potential long-term effect of a reduced herbicide input on the weed flora is expected to become visible.

WINTER WHEAT BASED ROTATIONS – ECONOMIC AND ENVIRONMENTAL EVALUATION OF IPM STRATEGIES

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The Directive 2009/128/EC requires the reduction of risks for human health and the environment as well as the mandatory implementation of the general principles on IPM. The assessment of the environmental impact and the economic feasibility of IPM systems are essential for farmers across Europe to meet the challenge.

The PURE the work group on winter wheat based rotations tested two different levels of IPM, an intermediate IPM (IS) and an advanced IPM strategy (AS), during three years in three geographical regions: i) North: Denmark and Scotland, ii) Central: Germany and Poland and iii) South: two locations in France. The on-station experiments covered the natural variation in pest occurrence, pest pressure and current practices (CS). Intermediate IPM and advanced IPM are employ a more diverse crop rotations by including spring-/ summer crops, the use of disease resistant varieties, diversification of cultural practices, extended use of existing warning and forecasting systems and crop-pest models. The IS focused on controlling the pests individually by employing a mixture of preventive and direct control methods to optimise control and minimise the risk of outbreaks. Additionally, cover/mulch crops, variety mixtures, delayed sowing dates in winter wheat and soil cultivation techniques and non-chemical tactics, including electron treatment of seeds, were tested in the AS. The interactions between pest categories were considered and preference was given to non-chemical methods also when these methods are not as effective as pesticides. Pesticide use was significantly reduced and preference given to selective pesticides.

The outcomes of the region-wise environmental assessment with SYNOPS and the results of the cost-benefit-analysis are presented.

Pesticide use was significantly reduced in the IS and AS compared to CS. As a result, the environmental risk assessment with SYNOPS shows a reduction of risks for aquatic organisms and the overall risk respectively for CS, IS and AS.

The cost-benefit-analysis evaluated the performance of the rotations across all on-station experiments. The gross margins were lower than in the CS in IS (2–44%) and AS (11–60%) respectively. An exception are the results of the Grignon on-station experiment (France) were the yields were higher and pesticides costs lower in the IS than expected, which resulted in higher production value and a 13% increase of gross margin compared to CS. The results indicate that the intermediate IPM systems in winter wheat based rotations can achieve a reduction of the environmental risks. The economic results deviate from the reference systems depending on the region and the possible yield penalties of the new IPM elements.

MAIZE-BASED ROTATIONS – AGRONOMIC EVALUATION OF IPM STRATEGIES

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Previous analyses highlighted that weeds and the European corn borer (ECB, *Ostrinia nubilalis* Hübner) are the major maize pests in Europe. Within the European Project PURE, fifteen on-farm trials were set up in five European countries (France, Germany, Hungary, Italy and Slovenia) during 2011–2014, to evaluate various IPM tools in grain maize, compared to the conventional strategy (CON). IPM tools tested against weeds included: 1) early post-emergence herbicide band application combined with hoeing (all countries), 2) early post-emergence herbicide broadcast application when indicated by a predictive model of weed emergence and after performing one scouting in the field (Italy), 3) tine harrowing at 2–3rd leaf stage of maize and low dose of post-emergence herbicide (Slovenia), and 4) mechanical weed control with harrowing and hoeing (Germany). Overall, IPM tools tested provided sufficient weed control without significant differences in yields and greatly reduced maize reliance on herbicides. Exception was the mechanical weed control that had low weed control and significantly reduced yields. IPM tools tested against ECB included biological control 1) using *Trichogramma brassicae* (all countries) and 2) Bt spraying (bio-insecticide using *Bacillus thuringiensis* var. *Kurstaki*) in Italy, Hungary and Slovenia. No differences were determined between IPM tools and CON in terms of plant damage and yields, whereas ECB pressure differed between countries.
Long-term on-station experiments (in France, Hungary and Italy) were also conducted during this period to evaluate two systems with different IPM level (IPM1-advanced and IPM2-innovative) against the CON in maize-based rotations. In France, IPM1 and IPM2 consisted of maize/soybean rotation with different levels of IPM against the CON continuous maize. In Italy and Hungary, IPM1 consisted of maize/winter wheat/soybean (peas in Hungary) rotation and IPM2 of maize/winter wheat/ (cover crop) soybean (peas in Hungary) (cover crop) rotation, both against the CON maize/maize/winter wheat rotation. Maize plant stand was optimal in all plots-countries due to general low pressures of soil pests. In France, weed control and maize yields were similar between CON (broadcast pre- and post-emergence herbicide) and IPM1 (broadcast pre-emergence, post-emergence in band plus hoeing), whereas weed control and yields were lower in IPM2 (pre-emergence in band plus hoeing). First analysis of the data in Italy showed that CON (broadcast pre- and post-emergence herbicide plus hoeing) had higher weed control and maize yield, followed by IPM1 (pre- and post-emergence in band plus hoeing) and IPM2 (post-emergence in band plus hoeing). Total broken plants (below and above maize ears; %) by ECB was higher under the IPM2 strategy (bio-insecticide; Bt) compared to the selective insecticide in IPM1 and broad spectrum insecticide in CON. In Hungary, CON (broadcast application) had higher weed control than IPM (band application) but similar yield with IPM1. Overall, it can be concluded that IPM implementation and success depend on specific local conditions as well as the level of weed and pest pressures. Knowing the history of the field in terms of weeds and monitoring pests and weeds during the growing season will determine the choice of IPM tools and the level of IPM implementation.

MAIZE-BASED ROTATIONS – ECONOMIC AND ENVIRONMENTAL EVALUATION OF IPM STRATEGIES

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Within the European Project PURE, on-farm trials were set up in five European countries (France, Germany, Hungary, Italy and Slovenia) during 2011–2014, to evaluate IPM tools against weeds and the European corn borer in grain maize, compared to the conventional strategy (CON). IPM tools tested against weeds included: 1) early post-emergence herbicide band application combined with hoeing (all countries), 2) early post-emergence herbicide broadcast application when indicated by a predictive model of weed emergence and after performing one scouting in the field (Italy), 3) tine harrowing at 2–3rd maize leaf stage and low dose of post-emergence herbicide (Slovenia) and 4) mechanical weed control with harrowing and hoeing (Germany). Cost-benefit analysis and the SYNOPS model were used to assess the economic and environmental impact of IPM tools vs. CON. Averaged over all tested IPM tools, total costs were lower in IPM compared to CON (–€5/ha). Gross margin was reduced in IPM (–€70/ha), but similar to CON when the only mechanical weeding tool was excluded. IPM tools against ECB were the biological control with *Trichogramma brassicae* (all countries) and Bt spraying (bio-insecticide; *Bacillus thuringiensis* var. *Kurstaki*) in Italy, Hungary and Slovenia. Total costs were higher in IPM compared to CON and ranged between +€20 to +€140/ha, with an average of +€70/ha. If only the trials in which a spraying was done in CON (Italy and Hungary) were considered, total costs increase ranged from +€5 (Bt-spraying) to +€20/ha (*Trichogramma*) in Italy and +€70/ha (*Trichogramma*) in Hungary. The difference in gross margin between IPM and CON ranged from –€155 to +€85 €/ha, with an average of –€55/ha. SYNOPS evaluation indicated a lower environmental risk of IPM vs. CON.

Long-term experiments were also conducted to evaluate two systems with different IPM level (IPM1-advanced and IPM2-innovative) against CON in maize-based rotations. In France, IPM systems consisted of maize/soybean rotation with different levels of IPM against the CON continuous maize. In Italy and Hungary, IPM1 consisted of maize/winter wheat/soybean (peas in Hungary) rotation and IPM2 of maize/winter wheat/ (cover crop) soybean (peas in Hungary) (cover crop) rotation, both against the CON maize/maize/winter wheat rotation. IPM-based strategies aimed at the reduction in or sustainable use of pesticides (e.g. band application of herbicides, mechanical weeding, bio-insecticide to control ECB). The ex-post assessment of their sustainability using an adapted version of the DEXiPM model indicated that the environmental sustainability of CON is "low" in the three countries, but improves to "medium to high" in the IPM systems. The economic sustainability of CON is medium in all three countries. The IPM systems had higher sustainability in Italy (in both IPM systems), but lower in Hungary (in both IPM systems) and France (in IPM2) as the gross margin averaged over the rotation level was lower than for CON. Overall, IPM was found to have lower environmental impact, whereas its economic sustainability depends on changes in costs of IPM tools, possible yield reductions and type of crops in the rotation compared to CON systems. IPM implementation is more profitable when replacing intensively managed conventional systems.

FIELD VEGETABLES – IPM-SOLUTIONS READY TO USE IN PRACTICE

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Due to new regulations IPM is mandatory in the EU since 1st January 2014. In the framework of the PURE-Project a range of different IPM solutions were designed for diverse *Brassica* crops as a model crop. These solutions were tested in six European countries with different growing and climate conditions: Denmark, France, Germany, Scotland, Slovenia and the Netherlands. *Brassica* crops were chosen as they require a high input of pesticides due to a wide range of pests attacking cultivated plants. The overall aim of the project was to reduce the reliance on pesticides and their risk to human health. Several innovative approaches were tested in on-station experiments. Promising IPM strategies were then tested on-farm.

The challenge for weed control was to get along with no herbicides. Experiments with non-intelligent and intelligent mechanical weed control techniques, including innovative devices, show that in principle the cultivation of transplanted *Brassica* crops is possible without using any herbicides. The trials also indicated that successful mechanical weed control was strongly dependent on the weather conditions. Non-chemical methods performed well in dry periods and were less effective when the soil was wet.

Several approaches were tested to control the cabbage root fly *Delia radicum* as it is the most important pest in cruciferous crops. Besides some approved chemicals like spinosad, only the use of entomopathogenic nematodes *(Steinernema feltiae)* and to some extent the release of predatory mites (*Macrocheles robustulus*) show promising results for controlling this major pest. At the moment the use of entomopathogenic fungi such as *Beauveria bassiana* or *Metarhizium anisopliae*, nitrogen lime (PERLKA®) and straw mulch cannot be recommend to combat this pest. Push-pull' strategies have also been tested against adults (France) and larvae (Scotland), but require further development (eg slow release formulations of bio-active plant volatiles).

Concerning aphid and caterpillar control, all tested products like the broad spectrum insecticides thiacloprid (Calypso®) and lambda-cyhalothrin (Karate Zeon®)), the selective insecticides indoxacarb (Steward®) and pirimicarb (Pirimor®) and biological products *Bacillus thuringiensis* subsp. *aizawai* (XenTari®) and rape oil (Micula®) performed well in controlling these pests even when applied after action thresholds were exceeded. When using biological products the number of sprays per season was slightly higher and their efficacy lower compared to chemical pesticides.

As swede midge and flea beetles are an increasing problem in several countries such as Slovenia, more attention have to be paid on these pests in the future.

CHEMICAL ECOLOGY STUDIES OF BRASSICAS TO UNDERSTAND AND INFLUENCE INFESTATION LEVELS BY THE CABBAGE ROOT FLY ADULTS AND LARVAE; TOWARDS A 'PUSH-PULL' STRATEGY FOR IPM

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Several plant traits above and below ground affect plant-insect interactions and shape host range and performance of herbivorous insects according to their degree of dietary specialization. Understanding these traits is of interest for the development of alternative crop protection strategies. In an Integrated Pest Management (IPM)context, an appropriate selection of plants can modify pest distribution at the field and plant scale. *Delia radicum*, the cabbage root fly (CRF), is a major pest of brassicaceous crops for which sustainable control strategies are currently lacking. In order to develop a "push-pull" strategy against the adults of cabbage root fly, we conducted a field study to both determine which plants affected pest infestation levels and influence egg-predation activity. This revealed that infestation levels of brassicaceous plants can vary considerably according to plant genotype and species, while the number of predated CRF eggs is only slightly affected by plant species. In a "push-pull" context, we demonstrate that different plants could be used to redistribute cabbage root flies in broccoli crops without compromising hcontrol by natural enemies. The importance of plant volatiles for infestation levels suggests a potential for developing a semiochemically assisted 'push-pull' system in which trap plants would be enhanced by release of attractive compounds.

Volatiles resulting from plant herbivore interactions play an important role in the behavioral decisions of phytophagous, predatory and parasitoid insects and could be used forIPM. However, documented studies on applications in the field remain extremely scarce. We have shown that dimethyl disulfide, a major compound emitted by brassica roots heavily infested by *D. radicum* larvae, was attractive for its main natural enemies and could lower the number of eggs laid by 60%. We conducted another field study to select additional volatiles that could be used in a push-pull approach. Several synthetic HIPVs, selected for potential action on the behavior of both the fly and its natural enemies, were placed in odor dispensers in broccoli plots. We confirmed the role of dimethyl disulfide in reducing *D. radicum* egg numbers on broccoli plants and identified other compounds that both influenced plant infestation by the fly and regulation by its main natural enemies. This is a first step in designing a push-pull method to control the adult CRF.

Specialised sampling techniques for identifying root volatiles *in situ* were developed and verified under laboratory, glasshouse and field conditions. SPME sampling combined with GC-MS analysis of time course studies identified a number of key root volatiles induced by larval damage. Several non-hosts were compared with host root volatiles using a video tracking bioassay (Ethovision software). Like CRF adults, larvae strongly responded to DMDS, showing a characteristic dose response. Root volatiles of onion (which share similar sulfur-based metabolites) was also highly attractive to larvae, indicating that adults make a more informed choice but larvae also respond to selected root volatiles. The identification of phytochemicals which either attract, repel or are toxic to larvae will be discussed in relation to future 'push-pull' strategies based on the chemical ecology of above-below ground interactions of this important pest and its natural enemies.

DECREASED FITNESS OF HERBICIDE RESISTANT WEEDS SUGGESTS OPTIONS FOR MANAGEMENT. CASE STUDY: *ECHINOCHLOA CRUS-GALLI*

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One of the major issues in weed management is herbicide resistance. The continuous build-up of herbicide resistant populations urges the implementation of Integrated Weed Management (IWM) to establish more sustainable cropping systems. This suggested new studies on the population dynamics to check if and how the resistance evolution process may be reversed through the implementation of important components of IWM such as crop rotation. Theoretically, to change the R/S plant ratio it is necessary that an agronomic fitness cost is present.

Several ALS-resistant populations of *Echinochloa crus-galli* have been found in Italian maize crops, mostly where continuous maize is cultivated. The aims of the research were: 1) to follow the evolution of R/S allele ratio when the selection pressure exerted by acetolactate synthase (ALS)-inhibiting herbicides is removed through the introduction of crop rotation and the use of alternative herbicides with a different site of action; 2) to characterize the possible fitness costs associated to the ALS-resistant *Echinochloa crus-galli* biotype.

Two situations were monitored in a field heavily infested by ALS inhibitors cross-resistant *E. crus-galli*: a) continuous maize with the best herbicide resistance weed management based on chemical solutions; b) three-year rotation (maize-wheat-wheat) plus final year with maize and no ALS treatments. Two seed stocks, susceptible (S) and resistant (R) with similar genetic background, were preliminarily selected from plants harvested in the experimental site and a three-year comparative growth analysis was conducted in the field. Barnyardgrass plants were grown without competition or in competition with plants of the other biotype (i.e. the S target was surrounded by plants of the R biotype and vice-versa) at three plant densities (3, 7 and 20 plants m^{-2}).

Molecular analysis indicates that a target-site mediated resistance mechanism due to a double mutation GC-AA, giving an Ala-Asn change in position 122 of the ALS gene, is involved in the R biotype. Weather conditions were very different during the three-year experiment (in particular in the second year). In general, a different development of the two biotypes was observed: R seeds germinated later than S ones and the development of R plants was delayed by about one week. This delay was maintained during the whole plant life cycle. In the first and third year, S plants produced significantly more panicles than R ones at all densities, whereas in the second year results were different for the spaced and 7 plants m^{-2} treatments. This indicates that a fitness cost is present in the resistant biotype, but that it is affected by weather conditions and, in particular, by rainfall and sowing time.

These results could be a good starting point for devising a resistance management strategy based on the differential population dynamics between R and S biotypes. The tested crop rotation coupled with the lack of selection pressure from ALS-inhibiting herbicides did not induce any change in the R/S plant ratio. This indicates that in a situation where ALS-resistance is well established, crop rotation and lack of selection pressure alone do not provide short-terms effects, so depletion of the resistant seed bank is the only way forward.

DECREASED FITNESS OF HERBICIDE RESISTANT WEEDS SUGGESTS OPTIONS FOR MANAGEMENT CASE STUDY: *ALOPECURUS MYOSUROIDES*

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Quantifying fitness cost has practical implication in HR management programs especially in IPM. This study investigated the main characteristics determining plant fitness in the entire life cycle of susceptible (S) and resistant (R) phenotypes from two Danish non-target site resistant *Alopecurus myosuroides* populations (ID33 and ID914). The competitiveness of S and R phenotypes in winter wheat was compared using the target-neighbourhood method. No significant differences were found in vegetative and reproductive ability between S and R phenotypes in two years glasshouse experiments and one year field experiment. The effects of temperature regimes (optimum; 17/10°C and low; 10/5°C day/night) and sowing depths (0, 1, 3, and 6 cm) on seedling emergence of non-dormant seeds were evaluated in pot experiments in a growth chamber. No significant differences in final emergence (E_{max}) across sowing depths were found between S and R phenotypes selected within population ID33. In population ID914, E_{max} of the R phenotype was lower than the S phenotype. Seeds of S phenotypes tended to emerge faster (low T_{E50}) than their corresponding R phenotypes especially at sub-optimal conditions. The burial depth inhibiting 50% of the final emergence (D_{50}) was similar for phenotypes of ID33 population. In contrast, the resistant ID914 phenotype had significantly lower D_{50} compared with the susceptible ID914 phenotype at low temperature. The results clearly revealed that at sub-optimal conditions the NTSR loci conferring herbicide resistance to R-ID914 were associated with lower fitness considering seedling emergence traits. The subtle fitness costs in R phenotype of ID33 population corresponded with a low resistance level compared with R-ID914. The results suggest that deeper soil cultivation and delayed sowing of autumn sown crops can make an unfavorable environment for R phenotypes. This study provides evidence for the hypothesis that fitness cost will increase in stressful condition. The results could easily be implemented in simulation models to predict the impact of timing and depth of soil cultivate on the proportion of resistant individuals in an *A. myosuroides* population.

AIRBORNE SAMPLING AND OPTICAL SENSING METHODS FOR MACRO SCALE MAPPING

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Emerging technologies evaluated in the PURE project can provide practical solutions to improve disease control in response to temporal and spatial differences in epidemics of fungal plant diseases. Evaluation of optical sensing methods to map disease foci for spatially selective treatment, found that remote sensing using satellite images has limited potential for disease control, except for mapping relatively static patches of some soil-borne diseases. Currently available data has relatively poor resolution (usually >1m^2 pixel size) and there are problems of revisit time and cloud cover. Secondly, because most fungicides are protectants rather than eradicants, established disease foci, which harbour a zone of incubating symptomless disease around them, are not controlled so for widely-dispersed polycyclic pathogens such as powdery mildews and rusts, by the time a few foci have been detected in a field, it is necessary to spray the entire field. More sophisticated proximal imaging techniques have greater ability to detect earlier, even pre-visible symptom stages of disease development for targeted control.

For diseases that develop from airborne inoculum, timing of disease control methods can now be improved using automated air sampling devices, integrated with appropriate diagnostic methods. A system developed under the 'SYield' project using an air sampler developed partly in the PURE project, has produced promising results for automatic detection of spores of *Sclerotinia sclerotiorum* in recent testing in Canada. Further development is ongoing to integrate the same MVI air sampler with novel isothermal DNA-based diagnostics. We can expect a new approach to precision agriculture to emerge from this technology – farm-based devices that give precision on when to apply fungicides and when to omit applications that may have previously been advised purely on weather-based infection risk, but which growers will know can be omitted if inoculum is not present. The technology will reduce costs and the environmental impact of farming.

Air sampling integrated with DNA analysis can also be used to monitor species composition and genetic changes within a species, such as fungicide resistance. Burkard seven-day spore traps were operated at rooftop level at Rothamsted Research (UK), Wageningen (NL) and at Slagelse (DK) for periods in the autumn and spring during 2011–2013. DNA extracted from daily samples was analysed using 454 amplicon sequencing. Numerous genera of fungal plant pathogens were detected.

A GENERIC DECISION SUPPORT SYSTEM FOR INTEGRATED WEED MANAGEMENT

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In the EU project 'ENDURE', 9 European Decision Support Systems (DSS) on integrated weed management (IWM) were analyzed. In the context of Directive 2009/128/EC, 'best parts' were identified, and a 'proof of concept' was designed. This DSS design specifically addresses 7 of the 8 general principles in the directive.
The DSS design includes best parts originating from 3 DSS, designed in Italy, France and Denmark, respectively. The DSS IT system architecture was designed as a generic frame suitable for customization for different countries, crops, climatic zones, etc. Using maize as a model crop, operational, online DSS prototypes were customized and made operational online for weed control in Slovenia, Italy and Germany.
These DSS prototypes include two different principles for quantification of needs for weed control, and integration of chemical and non-chemical (mechanical) control was enabled, too, however as proof of concept only.
Field experimentation in 2011 and 2012 in the 3 countries showed that the efficacy of pre-emergence applications of herbicides (existing practice) did not differ significantly from early post-emergence applications. This time-shift enables the DSS to evaluate needs for control and to target the use of control measures, including inherent characteristics of weed species, which is a basic principle in context of IPM.
In 2013 and 2014, field validation trials were conducted in the 3 countries, where DSS prototypes were tested against local 'best practice' recommendations. For practical reasons, mechanical control was not included in these trials. Results on yield and residual weed infestations indicate that some DSS prototypes controlled the weeds on level with local best practice treatments, and in some cases with a relatively low input of herbicides, too. These results indicate that the DSS design possess generic qualities, which may be suitable and potent for upscaling.

DELIVERING SUSTAINABLE FARMING THROUGH ON-FARM IMPLEMENTATION OF INTEGRATED FARM MANAGEMENT

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Land, water, biodiversity and natural habitats are under pressure from competing demands. Sustainable intensification is not about increasing the use of inputs, it is about wisely using knowledge and technologies, to grow production efficiency and intensify natures' interactions and benefits, through a more integrated approach.

Farmers need to be recognised for how they have adapted to the radically changed demands placed on our food system over the last 20 years. Encouragingly, new management approaches, environmental stewardship, market demands, social and environmental responsibility, improved engagement with retailers and closer relationships with consumers are all starting to help re-design our food systems.

Measuring such approaches is critical in order to help identify the most effective means of production; benchmark strengths; and create new solutions for reducing negative impacts. The LEAF Audit, and its new phase: the LEAF Sustainable Farming Review, built around the framework of Integrated Farm Management (IFM), is one such tool. Supporting farmers to build on their strengths and develop their businesses in a more sustainable, robust and resilient way.

The LEAF Audit is an online self-assessment management tool used by farmers in 33 countries, representing over 1.1million hectares, to help continually improve their implementation of IFM, a whole farm business approach that delivers sustainable farming.

Since its development in 1991, technology has changed significantly and the LEAF Audit has tracked changes over time of practices and processes implemented by farmers. LEAF has developed scoring based on responses from the LEAF Audit that show farm businesses are performing better in economic performance and environmental quality with a lower, but more rapidly improving, score in social health.

The LEAF Audit as a decision support system provides benefits in two ways: directly to farmers to encourage continual improvement of on-farm practices consistently throughout a world-wide supply chain base; indirectly through reporting on scores which allows information and support to be targeted in areas which most need it and demonstrating the performance of supply bases to others in the supply chain.

In 2015, the LEAF Audit will be replaced with the LEAF Sustainable Farming Review which will further improve usability, and implementation, for farmers, allowing more effective analysis and interpretation of the data for the benefit of LEAF, supply chains and the industry. In addition to the qualitative data, new metrics for more quantitative data are being developed.

As the need to develop farming systems that deliver more sustainable production increases, it is critical that we have the capability to track the changes that work and those that do not. The LEAF Audit and its new replacement: the LEAF Sustainable Farming Review, are effective management tools used by farmers to develop their farm businesses for the long term.

REPLACEMENT OF THE EUROPEAN WHEAT YELLOW RUST POPULATION

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The wheat yellow rust fungus, *Puccinia striiformis*, represents a crop pathogen with a high potential of aerial spread of spores across large areas and several invasions have been reported in recent years. We studied the origin and level of diversity of isolates of recently spreading yellow rust races in Europe using virulence phenotypic data of 2298 isolates sampled in seven countries between 2000 and 2013. A subset of 342 isolates was additionally investigated by microsatellite markers. At least four race groups of exotic origin (Warrior, Kranich, Triticale-non-aggressive and Triticale aggressive) were identified in the post-2010 populations, where the 'Warrior' race group was present in high frequencies in most of the West European countries and often associated with rust epidemics. Significant genetic divergence was estimated for 'Warrior' and 'Kranich' race groups from the pre-existing European population. It was concluded that they were of non-European origin being genetically related to populations in the near Himalayan region, which represents the pathogen centre of diversity. Although the overall diversity within Europe was higher among post-2011 isolates, compared to isolates sampled from 2000 to 2009, the within race group diversity was still much lower than in the recombinant source populations. The Europe-wide collaboration and compilation of data into a single dataset in a common database proved to be a major advance. It enabled us to identify the current invasion at an early stage, and to assess its implications at field level in many countries. Future collaborative efforts at the European scale should be continued and strengthened for timely early-warning of potential invasions of new variants of important crop pathogens with the capacity to spread very far within a very short period of time.

SPATIAL BLUEPRINTS FOR A MORE DURABLE USE OF RESISTANCE GENES AGAINST PLANT DISEASE

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Resistance to plant pathogens is a cornerstone of integrated pest management. Durable resistance is difficult to achieve because the use of plant resistance selects for pathogen genotypes that break resistance. The effectiveness of resistance genes is therefore often short-lived, and breeders have to continually adapt varieties to challenges by novel genotypes of pathogens. In a modelling study, we explore the effect of resistance gene deployment strategies and pathogen life-cycle components on the useful life of resistance genes. In particular, we try to identify gene deployment strategies that can prolong the useful life of plant resistance.

To develop blueprints for sustainable use of resistance genes, we developed a spatial model on spread of pathogen reproduction and spread on a national level. Blueprints consist of variety choice (gene deployment strategies) and characteristics of spatial deployment, i.e. fraction of resistant fields and degree of clustering of wheat fields. The tested gene deployment strategies include sequential use of varieties with single resistance genes, stacking of resistance genes within one variety, simultaneous planting of multiple varieties with a single resistance gene, and concurrent use that combines the use of a variety with stacked resistance genes and varieties with single resistance genes. We parameterized the model for *Puccinia striiformis* f.sp. *tritici*, the causal agent of yellow rust in wheat. Simulations were run for the whole of France.

The model results indicate that the useful life of a resistance gene is short when a small proportion of the pathogen population belongs to a resistance breaking genotype at the time a resistance is introduced in practice. Furthermore, differences between different gene deployment strategies are small if resistant genotypes are present from the outset. When a resistance breaking pathotype has to emerge by mutation, the useful life of a single-gene resistant variety is shorter than for a double-gene resistant variety (pyramiding of resistance genes). In an environment with a genetic bottleneck between growing seasons, resistance breaking pathogen genotypes for double-resistant varieties emerge each growing season, but are unlikely to survive to the next growing season. It is therefore highly unlikely that they will reach a high enough fraction in the population to render resistance ineffective. Strikingly, when a double resistant variety is deployed together with single resistance varieties with the same resistance genes (concurrent use), resistance breaking pathogen genotypes for double resistant varieties can reach high enough fractions in the population to render the double resistant variety ineffective.

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FUNGICIDE RESISTANCE MANAGEMENT

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The control of fungal plant pathogens has been characterized by repeated cycles of introduction of new fungicides and subsequent loss of efficacy due to the emergence and selection of resistant pathogen strains. Several strategies have been proposed to prevent, or at least delay, resistance problems. Such resistance management strategies should be based on evidence interpreted within a sound experimental and theoretical framework. Industry and regulatory decisions about fungicide resistance management often cannot wait for the accumulation of new evidence, so decisions should be taken by weighing the existing evidence and making judgments about the consequences should decisions prove to be wrong. In discussions on resistance management it is often not explicit what the evidence is, what is opinion and what is speculation. We use a principal from population genetics of clonal organisms to develop a governing principal and use this to review the existing experimental and theoretical evidence on the (i) management of application dose, (ii) managing the number of applications, (iii) use of fungicide mixtures, (iv) use of fungicide alternation, and (v) provision of pathogen refugia, and combinations of these. We review evidence and summarise evidence gaps.

WEED SUPPRESSIVE ROTATIONS: A MODELLING FRAMEWORK FOR SUSTAINABLE WEED CONTROL

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Land scarcity combined with an increasing demand for food, feed and fuel, puts an enormous pressure on agricultural land. Minimizing the negative effect of pests, disease and weeds contributes to increase, or at least maintain, current production levels. A study by Oerke (2006) estimated that, worldwide, actual yield losses due to pest, diseases and weeds are approximately 8% for each of the discerned categories. The potential yield loss of weeds, defined as the yield loss in the absence of control measures, was estimated to be twice as high as the potential yield losses due to pests and pathogens (34% vs. 17%). The large gap between potential and actual estimates of yield loss indicates that current weed control is relatively effective. The concurrent warning is that if we were to lose the ability for controlling weeds, we would face a tremendous problem. Obviously, sustainability of weed management systems is an important pre-requisite for securing future global agricultural production. Diversity is an important element of sustainability, as the continuous reliance on a single control measure will result in the selection of a few difficult-to-control weed species. The fact that herbicide resistant weed populations mostly develop in monoculture or simple rotation systems is a clear consequence of oversimplification.

Crop rotation is an important component of weed management. Each crop, through its sowing time, morphology and growth duration, but also through its associated crop and weed control management, creates the conditions for growth and reproduction of specific weed species, whereas it inflicts serious stresses on others. As a consequence, each crop is commonly associated with its own characteristic weed flora. The alternation of crops creates good opportunities for applying a more diverse set of weed control measures and for that reason crop rotation contributes to the durability of weed management systems. An important question is whether integrated weed management (IWM) strategies applied in a crop rotation context are able to provide a sufficient level of weed control in the short as well as in medium-long term, comparable to that achieved in one-sided herbicide-based management strategies. Are these more diverse systems able to prevent or revers herbicide resistance, or is the occurrence of herbicide resistance just delayed, and for how long? Finally, does IWM offer potential to reverse the situation on a field heavily infested with a herbicide-resistant weed population?

To answer these questions a modelling framework was developed. Starting point was a model to simulate the dynamics of a weed population in a monoculture cropping system. This model was extended to include the effect of several cultural weed control measures, and to cover the population development of multiple weed species, as well as herbicide and non-herbicide resistant biotypes of the same species. Finally, the monoculture cropping system was replaced by a crop rotation system. Scenarios were simulated to verify the potential of IWM to replace herbicide based weed management strategies and to avoid selection of herbicide resistant weed communities.

IS THE EFFICACY OF BIOLOGICAL CONTROL AGAINST PLANT DISEASES LIKELY TO BE MORE DURABLE THAN THAT OF CHEMICAL PESTICIDES?

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A meta-analysis of the scientific literature was conducted to assess the potential for plant pathogens and plant pests to become resistant to biocontrol agents. Although many plant bioagressors are known for their capacity to develop resistance to chemical pesticides or to overcome varietal resistance, only few studies have explored their ability to potentially overcome the effect of biocontrol agents. This presentation will be focused on plant diseases. The case of pests will be discussed in another presentation addressing the resistance of codling moth to *Cydia pomonella* Granulovirus (CpGV).

Reports on the effect of biocontrol agents on plant pathogens often consider only a single strain and one specific stage in the life cycle of the pathogen. However, among the available references analyzed in this review, some studies highlight differences in the sensitivity of various isolates of plant pathogens to biocontrol agents and the capacity of plant pathogens to adapt to biocontrol agents. Is it possible to link specific traits (of the pathogens or of the biocontrol agents) to the loss of effectiveness of biocontrol agents? Data are still too sparse to elaborate a general theory on the use of biocontrol agents in practice. This study highlights the necessity of proper management of these new products to avoid repeating the mistakes made with chemical pesticides.

Significant research efforts are still needed to acquire sufficient knowledge on the mode of action of biocontrol agents to optimize their use, to anticipate the potential failure of biological control and finally to integrate durability concerns in the screening procedure of new biocontrol agents and the careful management of their use once they become commercially available.

IS THE EFFICACY OF BIOLOGICAL CONTROL AGAINST INSECT PESTS LIKELY TO BE MORE DURABLE THAN THAT OF CHEMICAL PESTICIDES? LESSONS LEARNED USING CPGV TO PROTECT APPLES FROM CODLING MOTH

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A meta-analysis of the scientific literature was conducted to assess the potential for insect pests to become resistant to biocontrol agents. Although many plant bioagressors are known for their capacity to develop resistance to chemical pesticides or to overcome varietal resistance, only few studies have explored their ability to potentially overcome the effect of biocontrol agents. This presentation will be focused on the resistance of codling moth to *Cydia pomonella granulovirus* (Mexican isolate) (CpGV-M). The case of resistance to plant diseases will be discussed in another presentation.
The codling moth is the major pest of apple orchards, showing resistances to most chemical insecticides. The use of CpGV-M represented a primary choice for organic producers and a useful alternative in IPM.
Generalization of use of the almost pure genotype CpGV-M against codling moth resulted in an increasing failure of apple protection in various orchards in Europe, due to selection of a CpGV-M resistant insect genotype. Previous work allowed the identification of virus isolates active against these CpGV-M resistant populations, by screening virus natural populations and by selection of existing isolates. However, the question of an "arms race" remained. To evaluate the risk of development of new resistances it is important to understand how, in the natural environment, equilibrium is reached between virus and host populations, and how populations containing mixed genotypes behave.
Various aspects have been addressed both by partners of the PURE project or by other research teams, particularly, the cost for a larva to become resistant; the cost for a virus to overcome this resistance; the possibility of new kinds of resistance, and the importance of retaining genetic variability on the virus population. We can now draw a more global picture allowing us to better protect our orchards reducing the risk of new outbreaks.

TOOLS TO MANAGE SOILBORNE DISEASES

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Soilborne plant diseases can be caused by a wide range of pathogens, yet they share the ability to survive prolonged periods of time in the absence of a host. Application of pesticides is in most cases ineffective, especially when resting structures are involved. In addition they can cause unwanted environmental side-effects, as well as negative effects on non-target organisms. Other methods to kill pathogens, such as soil pasteurizing (high energy demand) and biological soil disinfestation (expensive) have their limitations as well. Therefore, control of soilborne pathogens in agronomic soils should be a combination of avoiding infestation with pathogens, reducing their population build-up, and management of soils as to maximize their disease suppression.

Reduction of soilborne diseases can be achieved by combinations of the following management strategies:

1. Avoidance of pathogens: using machinery and planting material that is free of soilborne pathogens.
2. Reducing the cropping frequency of hosts, which for the farm economics can be difficult to incorporate.
3. Cultural measures to prevent buildup of survival structures, e.g. the killing and cutting-off of potato haulms before *Verticillium dahliae* starts to form microsclerotia. However, the majority of soilborne pathogens produce their survival structure on infected roots.
4. Some specific effects of green manure crops, such as the cultivation of Tagetes to control *Pratylenchus penetrans* and the hatching of potato cyst nematode by *Solanum sisymbriifolium*.
5. Increasing the suppression of soilborne pathogens: suppression of soilborne pathogens is *a priori* a hard task because their survival structures are by definition less sensitive to invadors. There is a range of mechanisms involved, including specific and aspecific modes of action. In many cases both modes of action are quite active in agronomic soils, but they are rarely so prevalent that harmful expression of soilborne pathogens is nullified, especially not at high disease pressure.

To decide which management practices are needed, and eventually to set up early warning systems, soilborne pathogens need to be quantifiable at low densities.

AN EXPERIMENTAL TEST OF THE EFFECT OF MANAGEMENT STRATEGIES AND ROTATION ON PLANT-PATHOGEN SUPPRESSION BY SOIL MICROBIAL COMMUNITIES

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Soil is a highly complex habitat, with an exceptional diversity of microbial life. Interactions within the microbial community can be manipulated by rotation, tillage and organic amendment. However, the responses are not yet predictable, as the mechanisms linking these to soil suppression are not fully understood. The objective of the current research is to investigate and design management strategies to promote microbial mediated soil suppressiveness toward soil-borne pathogens and measure changes in soil biota due to these management strategies.

A wide range of soil biota as well as disease suppressive properties of the soil were assessed in a field trial with a winter wheat based rotation. The objective was to detect shifts in the communities of different soil biota due to cultural and management strategies. Such information could facilitate the design of management strategies to promote microbe-mediated soil suppressiveness toward soil-borne pathogens.

Two management systems were compared: (1) a control system including ploughing before sowing which is the currently applied system in the region, and (2) an innovative system targeting a better energy ratio, less greenhouse gas emissions, time saving for farmers and reduction of inputs especially nitrogen fertilization and pesticide applications. Both crop rotations consisted of winter wheat, winter oilseed rape, sugar beet and faba bean, but the innovative system had an additional crop linseed and cover crops between the main crops.

Soil management strategies and crop rotation influenced the communities of bacteria, fungi including arbuscular mycorrhizal fungi, and nematodes in soil. Community shifts could be either due to the preceding crop, or due to the management system. Soil suppressiveness differed for 1 out of 3 soil-borne pathogens tested. However, in general the natural soil in the assessed field was quite suppressive against the diseases, and several antagonistic bacteria (*Pseudomonas* and *Lysobacter*) were isolated from the soil samples.

The results showed the influence of management practices on soil biota and soil suppressiveness, indicating the potential of ecological engineering approaches to IPM through habitat manipulation at the field. However, distinct advises on management practices in relation to IPM will depend on the pathogens present in the field and the environmental conditions such as soil type, crop rotation and management. Extensive research is needed to get sufficient knowledge on the relevant soil processes before practical implementation is possible.

DESIGNING MULTIFUNCTIONAL MARGINS FOR BIOCONTROL IN WHEAT-OSR ROTATIONS

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Agricultural intensification has led to fragmentation of semi-natural habitats within the farmed landscape causing a loss of biodiversity and concern about the deterioration of important ecosystem services. Managed field margins that deliver multiple ecosystem services and take account of agronomic practicality could help to redress the balance and are essential if 'land-sharing' agri-environmental schemes are to be optimized. Provision for birds and pollinators has been a primary driver for field margin design to date and the value of margins for biocontrol of crop pests has been less studied. A number of studies have shown the potential of grassy margins which support cereal aphids and their natural enemies for improved biocontrol in cereal crops. However, most arable rotations in Europe include oilseed rape (*Brassica napus*) and we have shown that margins that do not contain brassicas do not support well the specialist natural enemies important in the biocontrol of oilseed rape pests.

Our work has focussed on designing field margins to increase the abundance of natural enemies and to provide biocontrol across the wheat-oilseed rape crop rotation. We tested a range of brassicas as potential 'banker plants' to provide resources for specialist natural enemies of oilseed rape pests. In the PURE project we assessed the value of field margins containing brassicas to invertebrate biodiversity and their effect on biocontrol in cereal and OSR crops. Our initial results suggest that while the brassica margins did increase the abundance and diversity of natural enemies found in field margins, there was little positive effect on biocontrol in the crop or on yield. It seems that getting biocontrol agents into the open field remains one of the greatest challenges in delivering crop protection via conservation biocontrol.

CONSERVATION BIOLOGICAL CONTROL AT THE LANDSCAPE SCALE

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Pest problems are usually viewed at the scale of the field, orchard or other individual crop unit, yet many pests are capable of moving between fields and may even spend part of their life cycle in habitats outside of the crop. Therefore, it should not be surprising that pests of various types respond to habitat characteristics of the landscape in which they appear or to landscape scale patterns in cropping and crop management. In addition to the direct habitat effects, a landscape may also act on pest populations indirectly and in a top-down way as a result of the influence of landscapes on the natural enemies of pests. It follows from these insights that to achieve a comprehensive picture of the factors driving pest pressure it is necessary to understand and account for the landscape ecology of pests and natural enemies. While this presents a challenge to modern IPM it also offers the opportunity to develop new tools for the regulation of pests through the appropriate management of farm landscapes.

To this end, a substantial investigation of ecological processes underlying the influence of landscapes on populations of pests and their natural enemies was undertaken as part of PURE with the overall objective of promoting the design and management of pest suppressive landscapes.

We used a combination landscape scale observational studies and computer simulation modelling to explore the ways in which the different habitats in the crop production environment can be managed.

In three contrasting studies the response of different pest and natural enemy groups to local and landscape conditions was assessed. Despite considering pests as diverse as moths and weeds, natural enemies such as parasitoids and generalist predators and cropping systems as different as cereal rotations and apple orchards, the significance of the surrounding landscape in determining the abundance of pests and natural enemies was clear. These effects included the influence of crop management at the landscape scale as well as non-crop habitats.

To explore the mechanisms underlying these responses and suggest possible landscape management strategies we have taking a modelling approach which combines the dynamics of crop production with the population dynamics of pests and their natural enemies. The approach has been designed to be flexible allowing us to look at a wide range of ecologically based strategies for pest control. Some of the ideas trialled so far include optimizing the use of pesticides in space and time, designing natural enemy based conservation strategies, and assessing the impact on pest control of interference between multiple natural enemies.

QUANTIFY THE CONTRIBUTION OF SEMI-NATURAL HABITATS TO ESSENTIAL ECOLOGICAL SERVICES – QUESSA

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The vegetation in semi-natural habitats supports ecosystem services (ES) essential for the development of sustainable farming systems. The EU project QuESSA aims to quantify some of the key ES (e.g. pollination and biocontrol) derived from semi-natural habitats (SNH) for the main European cropping and farming systems. This will be achieved by identifying key SNH according to their potential to support selected ES based upon vegetation traits. The ES delivery will then be verified through field studies in 16 case studies covering the predominant European cropping systems. A case study is defined by a unique combination of region, crop species, and service. Data will parameterise spatially explicit models to determine how vegetation composition, management, shape, area, and placement of SNH in agricultural landscapes affect the distribution of invertebrate based ecosystem services from farm to landscape levels. To investigate synergies and trade-offs in ecosystem services, multi-criteria analysis will be developed to combine a suite of modules in an integrative modelling framework. The project will produce guidelines, make recommendations to local, national and EU stakeholders and provide a web-based tool for farmers to enhance exploitation of semi-natural habitats for ES provision. QuESSA is funded by European Union's Framework 7 programme.

ARABLE LANDSCAPES AND MULTIPLE ECOSYSTEM SERVICES IN THE NETHERLANDS

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Ecological intensification of agriculture requires actionable knowledge for taking effective measures to support biological control, pollination and other ecosystem services in agricultural landscapes. We use a suite of empirical and modelling approaches to collect and synthesize information on the relationship between land use, habitat management and ecosystem service delivery in landscapes. We combine information from databases on plant communities in real Dutch landscapes with information on plant-insect associations and information on resource needs and dispersal of pollinators and natural enemies of crop pests to develop dynamic maps of ecosystem service provision. Assessments will be made of costs and profits. Engagement with stakeholders in two case study regions, the Hoeksche Waard and Flevoland, is pursued to take into account the services most valued by stakeholders such as farmers, water boards, nature conservationists, provincial and municipal authorities, etc. These analyses help to identify gaps in resource provisioning in the landscape that limit the delivery of ecosystem services. Furthermore, trade-offs and synergies may be identified. Such analyses may assist stakeholders in informed decision making and negotiation on habitat management and land use.

TOWARDS NEW CROPPING SYSTEMS TO MEET PRESENT AND FUTURE AGRICULTURAL REQUIREMENTS

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Across a continent such as Europe, Agriculture is probably the most diversified human activity depending on its products and socio-ecological contexts, but it faces a common set of challenges to produce food, feeds, energy or biomaterials in a trade-off space defined by economic, social and environmental drivers which are external to these agricultural systems. Crop protection is at the core of the desired transition pathways of cropping systems in this sustainability space: in the most productive and labour efficient systems (eg. wheat based systems in western EU or horticultural systems in southern EU) the challenge is to reduce the pesticide load of the system while in other systems a leeway may be to improve land and labour productivity through a better control of pests and diseases. Both require an integrated vision of the system to be managed, where interactions among components and with the environment become the major drivers of change compared to the additive and technology driven process which has shaped our current cropping systems. In this paradigm, crops are seen as agrosystems made of productive plants, service plants, soil layers, ecosystems providing input and receiving output. Designing and managing such agrosystems for a desired pathway in the sustainability space would require to act either on a component of the system (e.g. a pest or the receptiveness of the productive plant to it), on its active environment (e.g. replace a pesticide by another one with a better ecotoxicity profile) or on its passive environment (e.g. a certification scheme ensuring a better price for the product). From our analysis of the abstracts submitted to this session its seems that solutions to monitor and control the pests and diseases components are becoming operational both with conventional and biocontrol solutions. Research targeting the engineering of complex interactions among the agrosystem's components (productive plant, service plants, soils, pests and auxiliairies) have been launched in a wide range of crops (grain crops, orchards, vineyards, vegetables) but they are still in infancy with regards to knowledge and methods. Together with multicriteria assessment tools to ensure that these prototypes remain in the sustainability space, these research should ensure the re-design of pest suppressive and sustainable prototypes of cropping systems. But how these proof of concepts will be outscaled to farmers fields remains a major challenge to be addressed with industry and extension services, as it is likely that these complex agrosystems will have to be adapted to local conditions combining a specific set of resources and a desired position in the sustainability space for stakeholders, policies and supply chains.

ASSESSING THE SUSTAINABILITY OF CROP PRODUCTION SYSTEMS: IS A COMMON FRAMEWORK POSSIBLE?

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The integration of the economic, social and environmental dimensions of agriculture in a holistic assessment framework is essential to support the development of sustainable farming. Despite the fact that some sustainability assessment tools fulfil this condition, none of them is suitable for handling different assessment situations, especially considering diverse crop production systems – arable crops, fruits and vegetables – at different stages of development – research-desk prototypes (*ex ante* assessment) or in-field applied cropping systems (*ex post* assessment). The objective of this work is to explore the possibility of sharing a sustainability assessment framework that can be implemented on different objects for improving (i) the communication among the stakeholders involved in the development of sustainable farming and (ii) the action planning in terms of research as well as policy making.

In this respect, the adaptation of the qualitative sustainability assessment tool DEXiPM (i) from arable crops (Pelzer *et al.,* 2012) to other production systems and (ii) from the *ex ante* to the *ex post* assessment has represented a valuable source of ideas. Regarding the first task, three groups of experts have analyzed and modified the arable crop model in order to obtain suitable tools for assessing the sustainability of field vegetables, pomefruit orchards and grapevine systems. The majority of the modifications brought have involved the parts of the model ruled by technical and scientific knowledge (e.g. determining the fuel consumption), while few generic modifications have been brought to the part of the model that is ruled by stakeholder priorities (e.g. relevance of biodiversity in the environmental sustainability). Regarding the second task, the model structure has been modified case-by-case, according to the data available in *ex post* assessment, to integrate precise quantitative indicators in the qualitative framework. Two case studies have illustrated different ways of joining qualitative and quantitative data to get the best compromise between assessment precision and comprehensiveness.

This work has provided the formalization of a sustainability assessment framework suitable for different assessment situations. This articulates (i) a fixed core of generic agricultural sustainability issues hierarchically organized that can be weighted according to stakeholders' priorities and (ii) a set of indicators that can be flexibly estimated according to the assessment situation. Providing a shared and generic structure of assessment can positively harmonize, among various crop production systems, the way for setting goals and organizing them into a hierarchy, identifying bottlenecks and recommending adjustments towards more sustainability.

CBA: A COMMON CROSS-CUTTING METHOD APPLIED TO DIVERSE CROPPING SYSTEMS

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The most comprehensive summary of private, producer-level economic evaluations of IPM programs to date was developed by Fernandez-Cornejo et al. (1998), updating the prior work of Norton and Mullen. The 51 studies summarized highlight the fact that while most IPM programs increased profits, increased yields, and reduced pesticide use, these effects did not occur universally. The PURE project aimed at completing this evidence in six key European farming systems (winter-wheat based rotations, maize-based cropping systems, field vegetable crops, pomefruit, grapevine, protected vegetables) and a range of IPM solutions from intermediate (solutions easy to implement and scientifically validated) to advanced (solutions in the experimental stage). Collecting data on costs and benefits of IPM solutions and computing meaningful indicators is a first step to understand the drivers and incentives necessary for widespread IPM adoption. The cost-benefit analysis (CBA) methodology developed enables to aggregate all the information on monetary costs and benefits collected in the on-farm and on-station trials.

EUPHRESCO: AN OPPORTUNITY FOR PHYTOSANITARY RESEARCH COORDINATION AND FUNDING IN THE EPPO REGION AND ABROAD

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Euphresco (European phytosanitary research coordination) is a Network of research programme owners and managers focussing on phytosanitary research cooperation and funding. Euphresco was established in 2006 as an ERA-Net funded by the European Commission in order to cope with the threats linked to climate change and increased globalisation of trade, which exacerbate the introduction, establishment and spread of non-native invasive plant pests. These pests pose increasing risks to European agriculture, horticulture, forestry and the environment, while at the same time resources for national plant health inspection services, science programmes and research are declining.

Since 2014, Euphresco has become a Network supported by its members, 29 organisations from 22 countries aiming at strengthening the cooperation through trans-national research that optimises the use of limited resources.

The Euphresco secretariat is hosted at the European and Mediterranean Plant Protection Organization (EPPO), to allow Euphresco to benefit from the regional recognition of EPPO and its work for European cooperation in plant protection. Euphresco members are currently working on the organisation of the next (2015) round of funding of transnational research projects. The official topics will be advertised on the Network's website www.euphresco.net according to the published calendar of activities.

Euphresco aims to establish interactions with new organisations on two levels: full membership for research programme owners and managers, and participation in funded projects for research organisations. More information can be obtained by contacting the Network's co-ordinator.

COORDINATED INTEGRATED PEST MANAGEMENT IN EUROPE

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Most European countries are investing in research to reduce reliance on pesticides and the risks associated with their use. They must do this to implement the principles of Integrated Pest Management (IPM) as called for by Directive 2009/128/EC. Coordinating national research and extension efforts and pooling existing resources can create added value and synergies. The C-IPM project creates a forum for exchange and identification of IPM research and development priorities, provide recommendations on national and European research, connect existing initiatives, and coordinate joint transnational research calls.
The overall goal of C-IPM is to ensure a higher level of implementation of IPM among European farmers by creating synergies from national investments in research and extension. It builds on initiatives such as the network of excellence ENDURE or the Standing Committee on Agricultural Research Collaborative Working Group on IPM, which highlighted the feasibility of generating added value via joint activities that range from information sharing and the creation of knowledge hubs to the development of joint transnational actions. It will take stock of past and ongoing research projects on IPM, such as PURE.
The specific goals are to:

1. Identify synergies and gaps in existing national and transnational programmes and define an IPM-specific strategic research agenda and implementation plan;
2. Organise and fund joint transnational calls on IPM and minor uses;
3. Ensure better translation of national and European IPM-related programmes into applicable innovations.

C-IPM will support the formulation and implementation of national research programmes dedicated to the development of IPM strategies and contribute to the implementation of National Action Plans (NAPs), by facilitating the sharing of national experiences on pesticide-related policies.

Book of Abstracts

Poster Session

A SOCIO-ECONOMIC ANALYSIS OF BIOCONTROL IN PEST MANAGEMENT: A REVIEW OF THE EFFECTS OF UNCERTAINTY, IRREVERSIBILITY AND FLEXIBILITY (UIF) 1

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The Economic evaluation of integrated pest management strategy (IPM) is predominantly done through cost-benefit analysis. From a social welfare perspective uncertainty over benefits and costs, irreversibility effects and externalities need to be considered as well. We introduce the maximum incremental social tolerable irreversible costs (MISTICs), *I**, as a tool for such consideration. Only when the incremental benefits of an IPM strategy outweigh possible irreversible costs should the IPM strategy be introduced. The approach allows differentiating between an assessment of an IPM strategy from a private sectors point of view (excluding external effects) as well as from a societal point of view (including external effects).
The MISTICs, *I**, is estimated based on the option value and net present value calculation using Mcdonald-Siegel approach. European data (Eurostat) on conventional maize and potato production as well as secondary literature data on the efficacy of biocontrol against western corn rootworm (WCR) (*Diabrotica virgifera virgifera LeConte*) in maize and wireworm (*Coleoptera: Elateridae*) in potato are variables used in estimating the MISTICs.
The farm-level MISTICs per hectare for biocontrol of WCR in maize in a number of selected countries (Germany, France, Austria, Spain and Italy) was estimated at less than €150/ha while for potatoes was above €200/ha. This result therefore suggests that the introduction of biocontrol against wireworms in potatoes, given its higher MISTICs values, is more likely compared to the control of WCR in maize.
The model can be extended to include other factors such as regulatory hurdles which may delay introduction of an IPM strategy from a private sectors point of view, whereas the technologies that can be applied for effective IPM systems are delayed due to strict regulatory frameworks or unclear paths for registration.

KAP SURVEY IN IDENTIFICATION OF FARMERS' NEEDS AND RESEARCH PRIORITES

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In spite of numerous definitions on Integrated Pest Management (IPM), IPM can best be described as a farmer's knowledge and use of an optimal mix of pest control techniques and tools, taking into account a variety of other factors as: yield, profits, risk, sustainability and safety for consumers, farmers and environment. Thirty year experience in developed as well developing countries demonstrated that a FARMER should be the focal point in wide implementation of pro-ecological methods of plant protection against pests, weeds and diseases. This approach has been recently confirmed by obligatory implementation of the EU Directive 2009/128/EC.

Since 2002 the academic staff and M.Sc. students of Department of Applied Entomology of WULS-SGGW collected more that 1150 questionnaires on farmers' knowledge, attitude and actual production and plant protection practices (KAP survey), mainly from the fruit and vegetable growers. The major obstacles expressed by farmers in the common acceptance of IMP recommendations was related to the quality of training (to much teaching, not enough practices in field) and the negligence of marketing scheme for products of Integrated Crop and Pest Management (ICPM) programs. Independently of crop cultivated, the farmers' express the same shortcomings of the present access to knowledge: (a) still problems in the proper diagnosis of pest species and damage symptoms caused by abiotic and biotic factors; (b) optimization of economic use of biological control agents; (c) revised economic damage levels under multi-pest infestation; (d) prevention of pest, disease and weed resistance to the reduced pesticide options; (e) easier access to specialised professional extension service; (f) more publications and field guidebooks showing coloured pictures of various development stages of pests and pathogen infestation symptoms; (g) illustrations distinguishing some physiological disorders and mechanical damages from pathogen infection; (h) access to the Polish version of computer decision support systems for major crops.

The owners of larger farms and under higher external input implemented much more recommendations of IPM than in the farms under moderate and low input. Therefore a special attention during the IPM implementation period under the National Action Program of the EU 2009 Directive should be given to regions characterized by majority of commercial lower input in agriculture production, especially growing field crops. At the same time, a number of orchard owners and vegetable producers following the IPM principles may serve as the examples and demonstration that it is possible combine pro-ecological pest control methods with economic profits in a longer time frame by following strict ICPM principles.

The development and activity in training farmers in the GlobalGap and Integrated Production by the newly established private extension and consulting firms may support the governmental institutions in the specialized training of farmers and contribute to meeting conditions of the EU Directive on sustainable pesticide usage and IPM implementation in Poland.

THE REGPOT PROJECT – WARSAW PLANT HEALTH INITIATIVE'S CONTRIBUTION TO THE INSTITUTIONAL BUILDING AND HUMAN RESOURCE DEVELOPMENT FOR IPM 3

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Both the UNCED Agenda 21 (Chapter 14: Promoting sustainable agriculture and rural development) (Rio de Janeiro, 3–14.06.1999) and the Directive 2009/128/EC of the European Parliament and of the Council emphasized that IPM is a key component of sustainable farming with the objective to produce healthy crops. It is based on an understanding of ecology and the relations between crops and their pests (including pathogens and weeds), as well as an understanding of the environment in which the antagonistic organisms operate. It should be considered as an approach based on interdisciplinary collaboration between agronomists, plant geneticists and breeders, plant protection specialists, economists and sociologists.

Therefore the scientists of the Faculty of Horticulture, Biotechnology and Landscape Architecture of Warsaw University of Life Sciences – SGGW since 2001 undertook a number of initiatives to integrate expertise of different departments into coherent research and development project on plant health and IPM. Finally with the assistance of EC Directorate-General for Research & Innovation the Warsaw Plant Health Initiative (WPHI) project could start in 2011 to enhance both the research and networking capacity of academia in five key areas such as: entomology, plant pathology, crop production, plants-microorganisms interactions, and functional genomics. Project objectives are realized through, inter alia, staff exchange (15 long term training of young scientists and 47 short term visits by senior researchers to date), establishing two new laboratories, participation in 62 international conferences (21 oral and 42 poster presentations) and organisation of mini-symposia and workshops under a generic title "Frontiers of Plant Health" (19 in total).

In 2013 and 2014 the following mini-symposia took place: "Updated policy on plant protection research in response to new pathogens, pests and weeds emerging the European Union area", "Opportunities for enhancement of Integrated Pest Management", "Quality of fresh produce, herbs and vegetables – from field to fork", "Resistance to acetolactate synthase inhibiting herbicides: mechanisms, epidemiology and prevention", "Plant-associated microorganisms: an important key to a successful application of phytoremediation", "Classical and molecular approaches in plant pathogen taxonomy" and WPHI special sessions during 11th International Conference on Reactive Oxygen and Nitrogen Species in Plants.

CHALLENGES OF MARKET PLACEMENT OF PRODUCTS CONTAINING MICROORGANISMS AND THEIR UTILIZATION AS A PREVENTION OR INTERVENTION METHODS OF PEST CONTROL 4

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Following the general principles of integrated pest management set in the Directive 2009/128/EC establishing a framework for Community action to achieve the sustainable use of pesticides sustainable biological, physical and other non-chemical methods must be preferred to chemical methods if they provide satisfactory pest control. The use of numerous prevention methods of pest control is also recommended.

Products containing microorganisms can be used as prevention as well as intervention measures of pest control and therefore constitute a valuable tool from the point of view of integrated pest management. However their market placement raises some challenges like: shelf-life, proper application method and time, temperature of storage, transport and use, proper choice for particular use, overall safety and satisfactory effectiveness.

The market placement rules of products containing microorganisms differ in European Union depending on their intended use. From legal point of view microorganism used as intervention method of pest control are plant protection products and should be registered as such. The common rules for registration of plant protection products in EU have been in force since 1991. On the other hand so far there are no common rules as regards market placement of other products containing microorganisms.

PESTICIDE SPRAYING IN FIELD CROPS ACCORDING TO BIOMASS – RESULTS FROM 15 YEARS FARM FIELD EXPERIMENTS 5

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On the product label the producer of a pesticide give a value for the dosage in relation to the area unit (hectare). Regarding crop growth, agricultural fields are mostly not homogeneous. Soil, nutrient, and water content are mostly spatial variable within a field. Consequently, the yield potential is different. During the growing period the crop is forming a different biomass. Also the crop surface is different which has to be wetted by the spray liquid. Additionally the weeds are spatially different distributed within a field, characterized by a variability of species and age structure. Especially in the case of protective pesticides there has to be an even distribution pattern of the droplets. In case of systemic pesticides the active substance has to be penetrating from the spray deposit into the plant tissue to form a certain concentration. Because the biomass and plant surface of field crops and weeds do have a patchy occurrence, a uniform pesticide application with a constant application amount is no longer economical and ecological acceptable. There is a demand to improve the CO_2 balance and to reduce the pesticide input into the environment in the crop production process. In sparse crop and weed canopies the majority of the spray liquid often not reaches the target and goes unused to the soil. Areas with a low plant surface and biomass do not need so much spray liquid to form the same spray deposit compared to areas with a high plant surface/biomass.

To adapt pesticide spraying according to local plant surface/biomass, various sensors were developed at the Leibniz Institute for Agricultural Engineering Potsdam-Bornim (ATB) to control the application rate of a field sprayer. The distinctive sensor signal was correlated with plant surface and biomass which serve as parameters to vary the application amount by letting the concentration of the active ingredient in the spray liquid constant. Canopy sensing and spraying is done in one operation cycle (Fig 1).

Fig. 1. Camera sensor controlled herbicide spraying in winter barley

Field trials with the sensor controlled spraying technology were done in practical farmers' fields. The following pesticide savings were obtained compared to a conventional uniform spraying:

– herbicides: optoelectronic sensor 25%, camera sensor 27%
– fungicides: CROP-Meter sensor 22%
– insecticides: CROP-Meter sensor 13%
– growth regulators: camera sensor 22%.

In the sensor-controlled treatment of long term field trials no yield reduction and no higher occurrence of plant diseases, pests, and weeds has been found in the sensor-controlled plots in comparison with a common uniform treatment.

AN EFFICIENT APPROACH TO INVOLVE KEY STAKEHOLDERS FOR AN IPM MODEL AT REGIONAL LEVEL: THE CASE OF LIFE AGROINTEGRA 6

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The objective of LIFE AGROintegra project (2014–2017) is to minimize environmental risks related to chemical crop protection, by demonstrating the viability of more sustainable alternatives to pest control, on grain, vegetable, fruit and grapevine crops, in line with the Directive 2009/128/EC, establishing a framework for Community action to achieve the sustainable use of pesticides.
The specific objectives include:

- Bring innovative IPM techniques closer to farmers via practical demonstrations.
- Improve a collaborative pest monitoring and warning system.
- Develop a DST for farmers, proposing the best method for pests, diseases and weeds control in each specific plot and situation.
- Raise awareness among farmers and advisors on the advantages of more sustainable crop protection methods.
- Training and transfer of knowledge and tools in a fast, effective, continuous and comprehensive way, involving the agro industry and cooperatives.

The Government of Navarra (public authority responsible for implementing the Spanish National Action Plan for the sustainable use of pesticides in the region of Navarra – Spain) coordinates the project and the Institute for Agrifood Technology and Infrastructures of Navarra (INTIA), a public company attached to the former, is responsible for its technical implementation. The Union of Agriculture Cooperatives of Navarra (UCAN), with 169 cooperatives and 21.354 farmers, assures the participation and involvement of the farmers for the *on field* demonstrations and facilitates the communication and collaboration with them. Finally, the project ensures the representation of the food sector through CONSEBRO, the Agrifood Industry Association of the Ebro valley (Navarra, La Rioja and Aragón regions), with 104 companies, fully involved in the use of innovative IPM solutions for vegetables and minor crops and producing *zero residue* food.
The first stage of the project (2014) includes strong actions dedicated to the involvement of the stakeholders:

- Establishment of an **Action Group**: includes representatives from all stakeholders in Navarra (farmers, advisors, policy makers and actors of the food supply chain). The AG will meet three times a year and will be consulted for the strategic decisions of the project. At the end of the project the **IPM Platform of Navarra** will be established, gathering all stakeholders involved, as a permanent and open organization aiming at supporting the transition to more sustainable agricultural practices.
- Definition of the cooperatives, agro industries and farmers participating in the project that will later participate in:
  - **On farm** demonstrative actions
  - **Observers group** for the development of an improved monitoring and warning system
  - **Implementation of a DST** (HAD AGROintegra) and its technical and economic validation

LIFE AGROintegra is supported by the LIFE financial instrument of the European Community.

A WEB-BASED DECISION SUPPORT TOOL FOR CONTROL OF FUNGAL DISEASES OF EXTENSIVE CROPS

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In the framework of the environmental EU LIFE program, sigAGROasesor project (2012–2015) aims to develop an on-line platform that will support farmer's decisions with a customized GIS advisory tool. This platform is designed to provide economic and environmental sustainability indicators for field crops management and the traceability of agricultural products and activities. In line with current smart agriculture policies, sigAGROasesor offers a state-of-the-art technology platform with Decision Support Tools (DST) for the sustainable management of extensive crops, including tools for fertilization and irrigation scheduling, crop cultivar selection, control of diseases and sustainability indicators. A second version of the platform is currently under development, and it will be validated by farmers during the next growing season (2014–2015) over different regions of Spain.

A DST-Control has been implemented into the last version of the sigAGROasesor platform, with the general aim of helping users with decision-making processes associated with plant disease management. The first version of DST-Control is only available for the three major foliar fungal diseases of wheat, such as Septoria Leaf Blotch (*Septoria tritici*), Stripe Rust (*Pucciniastriiformis*f. sp. *tritici*) and Leaf Rust (*Pucciniatriticina*). These diseases will serve to test the current approach and more crops and diseases will be added in future versions of the tool.

The DST-Control becomes available within the sigAGROasesor platform when the user is registered and provides information about the management of crop, such as location and plot limits, cultivar, sowing date and irrigation data. Depending on user's selection, the DST-Control may generate for each of the three diseases, a calendar with daily disease risk from sowing date to 7 days after the query. A report including all the requested calendars is then provided to the user. For evaluating disease risks, information regarding disease susceptibility of sown cultivar and daily estimation of crop growth stage is used. If both criteria are positive, the DST-Control uses a new algorithm to evaluate whether meteorological conditions are suitable for the disease appearance (the computation is performed daily for the given period). This algorithm uses observations and weather forecast of daily maximum, minimum and average temperature and precipitation provided by the Spanish national meteorological agency (AEMET). The same algorithm is used for all simulations, but with five different disease-specific parameters. The algorithm has been initially calibrated for each disease using wheat experimental data collected in three contrasting regions in Spain (Andalusia, Navarre and Catalonia). These initial parameter values might be reconsidered after the analysis of data collected in the next growing season.

After evaluating disease risks, the DST-Control offers online information about the diseases, including a detailed description and a guide with the most effective management options and treatments for its control.

The initial version of DST-Control is operational in the current sigAGROasesor platform. However, some improvements are under design and it is planned to implement it in collaboration with AGROintegra project (LIFE13 ENV/ES/665), focusing in minimize the environmental risk caused by the chemical control of pests and diseases.

MANIPULATING FIELD MARGINS TO INCREASE PREDATION INTENSITY IN WINTER WHEAT (*TRITICUM EASTIVUM*) FIELDS IN DENMARK 8

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Habitat manipulation is a well-known practice in conservation biological control in order to enhance natural enemy density, and is a valid alternative to pesticide use. However, due to the striking differences in their ecology, generalist and specialist predators may show different response to habitat manipulation interventions. Moreover, clear evidence that to higher density of predators correspond higher density of predation may be not easy to find, due to possible undesired effects (i.e. intraguild predation, cannibalism, hyperparasithism). Additionally, quantitative estimations of predation rate are difficult to obtain, as predation may remain undetectable (i.e. hidden, night). We recorded the composition of predatory arthropod guild and predation rate within and along the edges of winter wheat (*Triticum aestivum*) fields surrounded by flowery or grassy strips from May to July 2014 in Denmark. Predators were collected using pitfalls traps and a suction sampler, while predation rate on aphids was measured using various exclusion cages (open, partially excluding, and totally excluding as control), and sentinel prey made of plasticine, that allows the identification of the predator marks. Ground beetles (Carabidae), rove beetles (Staphylinidae), spiders (Aranea), and parasitoid and predatory wasps (Hymenoptera) were the most common natural enemies during the experiment. We found significantly lower number of generalist predators (but not specialists) in flower vs grass margins ($p<0.05$) from the suction samples. Activity density recorded using pitfall traps did not show significant difference in flower vs. grass margins for either specialist or generalist predators. Mean survival time of in-field aphid colonies was shorter (5.8 days) near flowery vs. grassy (9.9 days) edges. However, the Biological Control Index was not different. Forty-six % (n=756/1637) of the sentinel prey were attacked after 24 h mostly by chewing insects (88%, n=665/756 of the bites), followed by small mammals (13.2%, n=100/756), and birds (1.3%, n=10/756). Predation rate by chewing insects was higher in grass than flowery margins (48.9%, n=436/892 vs. 30.7%, n=229/745), and also higher in the edge than within field (45.3%, n=371/819 vs. 35.9%, n=294/818). In the flowery strips, predation was slightly higher within the field than in the edge (30.9%, n=115/372 vs. 30.6%, n=114/373, respectively), while in grassy ones, it was higher in the edge than within field (57.6%, n=257/446 vs. 40.1% n=179/446). Our preliminary results suggest that flowery strips enhance specialist but not generalist predator abundance in the field edges, and that a correlation between generalist predator abundance (especially of ground beetles) and predation rate on artificial sentinel prey may exist.

DEXiFruits: AN EASY-TO-USE TOOL DERIVATED FROM PURE RESEARCH TO EVALUATE THE SUSTAINABILITY OF FRUIT PRODUCTION SYSTEM 9

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The overall objective of PURE was to provide practical and innovative production strategies to reduce dependence on pesticides in selected major farming systems in Europe. During PURE, the environmental, economic and social sustainability of the innovative production systems were assessed *ex ante* (i.e. before testing) and *ex post* (i.e. after on-station and on-farm experiments), using the multi-criteria assessment tool DEXiPM-pomefruit® complemented by the research tool SYNOPS, to assess the environmental risk and an economic model at the supply chain scale. These assessment models were used to judge the different IPM tools and solutions in their efficacy (pest/disease incidence, yield/quality losses, pesticide applications), cost benefit ratio, pesticide residue levels and their health risk for workers and environmental risk.

Since this evaluation process can encourage the implementation of these new production strategies, the DEXiPM tool was adapted to the stakeholder use in the frame of the French National Action Plan for pesticide reduction.

Based on the DEXiPM-pomefruit tool, DEXiFruits has been designed to make an *ex post* assessment of the sustainability of orchard systems. This model is based on a decision tree breaking the decisional problems of sustainability assessment into simpler units, referring to the economic, social and environmental dimensions of sustainability. The specifications were: to assess the 3 pillars of the sustainability, to be a stand-alone and easy-to-use tool, to match with easy collected data, describing the production system.

Both the Pure work of the pomefruit workpackage and the adaptation process to create the DEXifruits tool will be presented.

IPM-STRATEGIES FOR CEREAL PRODUCTION – A NORWEGIAN CASE STUDY

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In Europe there is an on-going process on implementing regulations aimed at reducing pollution from agricultural production systems, i.e. the Water Framework Directive and the Framework Directive for Sustainable Use of Pesticides. At the same time, there is an increasing focus on food security possibly leading to continued intensification of agricultural production with increased use of external inputs, such as pesticides and fertilizers. Application of sustainable production systems can only be achieved if they balance conflicting environmental and economic effects. In Norway, cereal production is of large importance for food security and reduction of soil and phosphorus losses, as well as pesticide use and leaching/runoff in the cereal production are of special concern. Therefore, we need to determine the most sustainable and effective strategies to reduce loss of top soil, phosphorus and pesticides while maintaining cereal yields. A three-year research project, STRAPP, is addressing these concerns.

A catchment area dominated by cereal production is our common research arena within STRAPP. Since 1992 a database (JOVA) with data for soil erosion, nutrient and pesticide leaching/runoff (i.e. concentrations in stream water), yield, and agricultural management practices (fertilization, use of pesticides, soil tillage and rotations) has been established for this catchment allowing us to compare a unique diversity in cropping strategies in a defined location.

An important part of STRAPP focuses on developing 'best plant protection strategies' for cereal fields in the study area, based on field inventories (manual and sensor based) of weeds and common diseases, available forecast systems, and pesticide leaching risk maps. The results of field studies during the growing seasons of 2013 and 2014 will be presented, with a focus on possible integrated pest management (IPM) strategies for weeds and fungal diseases in cereal production. We will also present the project concept and methods for coupling optimized plant protection strategies to (i) modelling of phosphorus and pesticide leaching/runoff, as well as soil loss, and (ii) farm-economic impacts and adaptations. Further, methods for balancing the conflicting environmental and economic effects of the above practices, and the evaluation of instruments for increased adoption of desirable management practices will be outlined.

TRACING EXPERIMENT TO EVALUATE THE FATE AND BEHAVIOUR OF A PESTICIDE'S MIXTURE UNDER CONTROLLED CONDITIONS FOR DRAINED SYSTEMS

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The diversity of processes involved in pesticide fate in the groundwater resulted in a large variety of models. 1 dimension leaching has been studied many times with various models. However, drains have influence on the watertable shape and consequently the drained flow might differ from a classical vertical water transfer. In order to understand the characteristics of pesticide leaching under drained conditions, a tracing experiment with 28 different molecules was realized under controlled conditions. The study was mainly focused on the hydraulic part of the drained flow and the modelling using HYDRUS software combined with the use of ideal fluorescent tracers helped to set up the specificities of the water flow. The selection of the pesticides was based on agricultural practices in the Northwestern part of France and therefore the concentrations applied were calculated to reproduce the practices on the field. We used 4 fungicides and 23 herbicides with a wide range of sorption potentials (from 15 to 2000 cm^3/g). The experimental device MASHYNS is a 1 m^3 bunk (2m*1m*0.5m) that simulates drainage flow. The soil is a mixture between silt and sand that results in a hydraulic conductivity of 1m/day, the organic matter content is 2% and the porosity 43%. 3 dye tracers are first tested to find the most ideal water tracer in a 1D system tracing and then used on MASHYNS to determine the hydraulic flow. Both tracers and pesticides were spread on top of the device trough a sprinkling system and the water inlet was set up to represent the annual hydrology that happens on the field (350mm of drained water). Thus a constant high flow rate is needed to allow the complete leaching of all molecules. Pesticides are spread at different periods, to which a specific watertable height corresponds. Data are collected at the outlet for both tracers and pesticides (spectrofluorimeter, chemical analyses). Those data are then compared with results from modelisation using the software HYDRUS based on Richards equation and the convection-dispersion equation. Parameters such as hydraulic conductivity, saturated water content, dispersivity both longitudinal and transversal are evaluated by inverse modelisation. Complex processes such as physical non equilibrium with immobile water content, preferential flow or even macropore flow, may occur during the experiment and have to be tested by the model. Amino-G acid (AG) appears to be almost an ideal water tracer. Tracings in both 1D and 2D proved that electrical conductivity and AG's concentration breakthrough curve (BTC) were almost simultaneous. Tracing in 2D though shows some unexpected behaviour, with several peaks on the BTC and a long solute tail mainly due to the drain effect. And modelling highlighted the fact that numerous processes combined might have resulted in so many peaks in the BTC. Chemical analyses allowed the pesticide's sorption potential evaluation via comparison within results from modelling.

GLOBAL SENSITIVITY ANALYSIS OF PESTICIDE LOSSES IN STRUCTURED TILE-DRAINED SOIL

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Diversity of processes involved in pesticide fate leads to create complex modelling tools. Interactions between processes and parameters can make results interpretation difficult or superficial. In order to understand which parameters influence pesticide exportation in a drainage context, a global sensitivity analysis was conducted with the model MACRO on one of the six European drainage scenarios from FOCUS (2002) called "La Jaillière" and based on a western French site. Sensitivity analysis (SA) appears as a useful tool to identify key parameters. However, the most used SA practice seen in the literature is that of 'one-factor-at-a-time' (OAT) which consists in analysing one parameter variability influence on various models outputs while the other inputs are fixed. As criticized by Saltelli et al. (2010) OAT strategy is definitively not a sufficient option. Thus, this work objective is to use global sensitivity analysis methods to determine key sensitive parameters in regards of water and pesticide fluxes in drainage and runoff flows with a calibration perspective. Two complementary sensitivity methods have been selected. The first one called: "Morris method" was used to analyze influence of 48 main parameters on water and solute fluxes. This screening method provides qualitative information and is here performed to select the most significant parameters to be analyzed with a more quantitative method. Secondly, Sobol method was chosen as it's a very robust one which provides first and total sensitivity indices (Yang, 2011)]. Simulations were performed with the software CEMAFOR (Cheviron, 2012) which couples MACRO, used as slave model, with the optimisation tool PEST (Doherty, 2004). This study focuses on the evolution of parameters influence depending on adsorption and degradation initial value. For that, a set of 16 hypothetical substances were evaluated. A C.V of 20% was used for adsorption and degradation parameters. Others inputs values (distribution and ranges) were based on literature values as far as possible. Results show a strong influence of initial physico-chemical properties on key processes that govern pesticide exportations. Thus, calibration of pesticide leaching seems to be highly substance specific. Influent parameters related to water output (balance and dynamic) don't necessarily fit well with solute results. Thus, this study tends to prove that water and pesticides transfers should be calibrated in a unique step, as was suggested by Moeys et al. (2012).

ELICITRA – INTEGRATED FRENCH NETWORK PROMOTING THE STRATEGY OF PLANT RESISTANCE INDUCTION BY ELICITORS THROUGH RESEARCH, TRAINING AND DEVELOPMENT

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Agriculture must face challenging and apparently contradictory issues: becoming both competitive and sustainable. The current reduction plan of pesticide use, occurring throughout Europe, must therefore be accompanied by the development of efficient environmentally friendly methods in crop protection. Among them, the enhancement of plant defence mechanisms by elicitor treatments is one of the most promising strategies and has become a major topic of current research.
Elicitra is a French network co-animated by ARVALIS-Institut du vegetal, Vegenov and INRA. Its main mission consists in promoting plant protection by induced resistance through research, training and development. This network is dedicated to a large range of plant productions: field crops, vegetable, fruits, vine, ornamental plants and medicinal plants. It includes partners from public research, technical institutes, universities, agricultural colleges, various actors of the crop industries and competitive clusters. By bringing together various partners with different skills ranging from field to lab and from research to training, the understanding and development of this alternative approach is accelerated.
Elicitra is supported and financed by the French ministry of agriculture. It was launched in 2011 and will work until 2018.
Main Results:
Network & communication
– An active community about elicitor
– A web site : www.elicitra.org (in French)
– A 2 days meeting in 2013 (150 participants)
– A scientific & technical monitoring : **Elicitr'Actu** (4 times a year)
Scientific & technical results
– A definition of what is an elicitor
– A data base with the main experimental results
– A guide for experimental practices
Impact on research
– Reorientation of public research priority
– A list of research priority (based on an exhaustive work about plants diseases and elicitation potential progress)
– New research projects
During the next 4 years, Elicitra will keep on working about sharing results, communication and research with 5 main axes: assessment of new elicitors, plant response to elicitor, application condition, elicitor in IPM and agro ecology, unintended effects.
Elicitra is an open network: contribution and exchange with elicitor actor (in France and abroad) are welcome.

A FRENCH NETWORK FOR THE MONITORING OF CROP PESTS IN A CONTEXT OF IPM IMPLEMENTATION

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The crop health bulletins (BSV) have been implemented since 2009, to succeed the agricultural warnings. They answer the axis 5 of the National Project Ecophyto 2018 which aims to „ Strengthen the monitoring networks of pests and the non target effect of the use of pesticides „.
The protocols were harmonized for the most part of the arable crops. They describe the methods of observations and the variables to be used by all contributors.
The observers are technicians of cooperatives, trading companies, farmers' associations, and institutes, as well as farmers themselves. Advise centers rely on the bulletins to draft their recommendations for the farmers at the field scale.
Every week, the observers record the observations carried out in the fields they are in charge of. With the Internet portal Vigicultures® tool, they can have a look on all observations presented in maps, graphs or templates. Vigicultures® is an Internet portal to provide data from observation networks to the crop health bulletins (BSV). Launched in 2008 the network has today some 30,000 plots, and more than 2 million observations. The data are then validated and linked with forecast models. The bulletin is prepared by each crop facilitator, endorsed by referent groups, and published on the web site of the Regional Chambers of agriculture, as the web-based platform **www.yvoir.fr** of Arvalis-Institut du végétal.
Beyond this weekly information to help the decision-making, it is important to progress in the protocols for field observations and the available monitoring tools. Annual crop-health reports allow a preventive multi-year management against some pests, in particular by preventive measures. The observations also help the technical institutes (ARVALIS Institut du végétal, Cetiom, ITB) to establish regional and national assessments. The database gathers enough information to proceed with the analyze of annual data to allow a year-by-year comparison. The poster will present interannual evaluations of cereal and beet diseases, as well as the weevil of the terminal bud of the rape seed.

EVALUATION OF ELICITOR'S ABILITY TO REDUCE THE USE OF FUNGICIDES TO CONTROL POTATO LATE BLIGHT AND WHEAT SEPTORIA LEAF BLOTCH

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Due to environmental and human health concerns, French authorities have planned to reduce the use of pesticides in agriculture (Ecophyto plan). In parallel, according to an ECPA studies, the number of active ingredients registered and available for use, continues to decrease dramatically like the number of new molecules in the pipeline, which has been divided per two in 10 years. Consequently there is an increasing need to innovate, and especially for the development of low risk products or technics, to maintain the competitiveness of agriculture.

So, ARVALIS tests new systems or technology to control diseases with fewer amounts of chemicals, such as decision support systems, cultivars resistance, plant defenses stimulators (elicitors) or reduced doses of fungicides.

Intensive fungicide use is the most common way to control potato late blight (average number of fungicide treatments is about 14 to 15 per year in France). Different elicitors have been tested in potato late blight field trials, in semi-controlled conditions (misting system + inoculation), based on weekly applications from beginning of June to end of July at Boigneville (2012, France).

Some alternative products show promising results especially in combination with a reduced dose of fungicides. In trials with different elicitors, it was found that phosphites based products show a good efficacy to control late blight. However, they are not enough effective to be used alone. The use of 750 g / ha of PO3 in combination with a half dose of fungicide, was nearly as effective as the full dose of the same fungicide. The dose of 1000 g / ha, again in mixture, with a half dose of fungicide, would have been probably slightly better, more stable and safer for users.

Another product has so far shown some very interesting results. This product contains only plant extracts (saponin, glutathion and oligosacharin) without any phosphites and could be used in organic farming (or as biocontrol product).

As a conclusion for potatoes, a 50% reduction in use of fungicide (Ecophyto French plan goal) on potatoes seems possible, facilitated by the large number of treatments, the good efficacy of fungicide half-doses, and with the help of elicitors in mixture.

Researches on septoria (*Zimoseptoria tritici*) are far less advanced. Little attention has been paid until now to cereals, in term of elicitors, despite the fact the wheat surface represents in France about 5 millions ha cultivated and is sprayed on average twice a year.

First trials show that replacing a half dose of the first treatment (conventional chemical) by a double application of one elicitor is a reasonable goal. Among the different elicitors tested, with this protocol, in the field at Boigneville on three cultivars (France, 2012), (microorganisms extract, *Trichoderma harzanium* extract, phosphite based product, chitosan) only a chitosan based product, has given regular and acceptable results.

PHYTOSANITARY PORTAL NEW TOOL FOR CZECH FARMERS TO ENCOURAGE IPM UPTAKE

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In order to ensure obligations arising from EU legislation (Directive 2009/128/EC), the Central Institute for Supervising and Testing in Agriculture (CYSTA) has developed a new tool serving as an important resource of information for implementing of IPM in the Czech Republic. Phytosanitary portal includes theoretical data – general information about main grown crops (field crops, permanent cultures and vegetables) and varieties, recommended agrotechnology, pest, diseases, weeds and abiotic disorders. Except of general data, there is information about thresholds, monitoring methods, prognosis and recommended preventive and direct measures, non chemical included. The most helpful part represents red-yellow-green list of registered pesticides. This list is generated from existing regularly updated list of pesticides according to the eco-toxicological characteristic that represents risks for water organisms and environment, soil organisms, bees, non-target organisms, birds, mammals, non-target plants and humans. The red-yellow-green list of pesticides is automatically generated for each indication (crop/pest combination). Another useful part of portal represents photo gallery – photos of crops, pest and diseases, weeds and abiotic disorders that serves as a diagnostic key. Phytosanitary portal is being under further development. Regular reports of state monitoring of harmful organisms have been attached recently. Famers can use also current prognostic tools for occurrence of aphids, forecast system for Potato late blight, Septoria leaf blotch, Cercospora of beet and SET´s for main insect pest. For now, there are data about 40 crops, 138 insect pests, 131 diseases and 45 abiotic disorders. Look into the future, except of feeding system by additional data, Phytosanitary portal will be interlinking outcomes of research projects on resistance or prognosis of biotic and abiotic disorders with functions helping to farmers with decision. The future idea is that farmers will have registered access into the system free of charge. This registration will bring benefits representing data of actual local occurrence of harmful organisms, early warning system (via email or SMS) included. Additionally, each user might insert own data into the online prognostic programs to get back concrete results or put his own observation of actual occurrence of harmful organisms to extend monitoring network. Phytosanitary portal represents robust tool for Czech farmers that will contain comprehensive information about agronomic methods, pest and diseases, DSS, usage of pesticides and resistance to chosen active ingredients.

VIPS – AN OPEN SOURCE TECHNOLOGY PLATFORM AIMED AT INTERNATIONAL COLLABORATION ON IPM

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VIPS is a technology platform for IPM, where results from forecasting models can be distributed to users anywhere. The model output views are flexible and simple to incorporate in existing web sites or distribute on smart phones and tablets. Worldwide cooperation on development, implementation, testing and validation of forecasting models is made easy in VIPS. The source code for the platform is released under an Open Source License, guaranteeing partners that their efforts will be mutually shared and beneficial. The VIPS system is based on 14 years of experience with a web based forecasting and information service for integrated management of pests and diseases in cereals, vegetables, and fruit crops in Norway. A totally reconstructed and internationally adaptable version of VIPS is tested internationally in 2014. The system allows for local adaptations, including language, incorporation of models and other services. Our aim is to create a technology platform for international collaboration on IPM.

Through VIPS, all available IPM-tools for pests and diseases within a cropping system can be implemented. This provides flexibility for further development, validation of models and implementation of new tools, where the end-users do not have to relate to several different platforms. VIPS can thus be used for research, development and extension, all by use of one system. This enables a quick release of new tools, without any delays or reprogramming of models when research and development is completed.

We are interested in cooperation on developing the system, for example through joint R & D projects that include implementation of forecasting models and development of applications. The forecasting system will also be available as a cloud service. Bioforsk's researchers and ICT personnel will assist collaborators in configuring existing, relevant forecasting models and distribution of the model output.

PREMISE INSECT MODEL: INTEGRATED POPULATION DYNAMICS MODEL FOR THE EX-ANTE EVALUATION OF IPM AGAINST INSECT PEST 18

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A cost-effective application of IPM against an insect pest depends on the number of insects at the time of application. Several conditions influence the lifecycle and number of generations within a year. The climate, and especially the temperature, is a predominant condition that influences insect development and survival. In regions with Mediterranean climate the number of generations and reproductive capacity is much higher compared to regions in Northern Europe. Additional conditions like rainfall, wind, regularity of canopy, light proximity and the proximity of other plants also affect for example the severity of codling moth in an apple orchard. The interaction between the life cycle of the insect (influenced by these conditions) and the application of measures is of such complex nature that an integrated population dynamics model is required to estimate ex-ante the cost-benefit of IPM options.
From the paper of Shaffer and Gold (1985) as starting point, a population dynamics module based on iterative-cohort technique has been developed in Visual Basic. The module distinguishes successive stages (e.g. adult -> eggs); each stage with a temperature dependent (hourly) development, production and loss. On daily basis the number of individuals within each stages can be estimated. Site specific conditions influence the population dynamics. With the IPM-measures module the user can define and select the measures, the period of their application, the stage that is affected (e.g. egg treatment) and the effect on the population. After measures are applied, an economic partial-budgeting module calculates the costs (chemicals, nets, labour, equipment) and returns based on yield, price and price reduction. PREMISE (**P**est **R**isk **E**valuation **M**odel by **I**ntegrating **S**tage **E**ffects) integrates these modules. The user can easily compare IMP options with well-timed applications and thus perform ex-ante cost-benefit evaluation.
For a case study the generic PREMISE Insect Model has been populated with life cycle parameters of *Cydia pomonella* (L.) in an apple orchard. Field data from an experimental orchard design (Gotheron experimental unit in France, season 2013), which has been described earlier by Simon et al. (2011), were used to calibrate the model which needs further testing with other years and in other countries. For this season and region the field and model results are in the same range of values.

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DOES BABA CAN MITIGATE THE EFFECT OF ARTHROPOD PEST INFESTATION ON EGGPLANT? 19

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Although the eggplant fruits are known to be rich in antioxidant secondary metabolites, they still remain a niche crop in Poland. They are largely cultivated under cover, and require chemical protection, because frequently are infested by thrips, mites, white flies, aphids and many other herbivores.

Suppression of pest herbivores to low densities with non-chemical, biological methods combined with simultaneous strengthening eggplant self-defence, could result in effective protection, compliant with the EU Directive (2009/128/EC).

It is known that a non-protein β-aminobutyric acid (BABA), applied as a priming agent, may confer protection against a broad spectrum of biotic and abiotic stresses. It can sensitize plant by the activation of so called 'primed state' in which the plant is able to respond more effectively to pest attack than other non-treated plants.

The eggplants (*Solanum melongena* L. ScorpioF$_1$) were grown on soilless media in greenhouse, to mimic the usual production conditions. The plants were treated with water (control) or with BABA at 25 mM or 50 mM concentrations applied as seed imbibition (SI) or soil drench (SD). BABA-untreated and treated plants were naturally infested by a mixed population of thrips and two-spotted spider mites. Following the infestation, eggplant growth, development and leaf chlorophyll fluorescence (Fv/Fm – maximum quantum efficiency of PSII, PI – performance index, øPSII – quantum efficiency of PSII), as well as pest performance, were assessed.

In the present study, simultaneously feeding thrips and mites caused only week changes in eggplant growth and development. Measurements of chlorophyll fluorescence parameters suggest that BABA has the capacity to mitigate negative effects of these pests, at least to some extent. However, its effectiveness depend on BABA mode of application, concentration and pest density.

SPECIFIC GUIDELINES FOR INTEGRATED PEST MANAGEMENT IN STORED PRODUCT PROTECTION SECTOR 20

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Crop or sector specific guidelines for integrated pest management (IPM) (hereafter 'guidelines') is one of several measures under the heading 'research, practical use and trade' within the National action plan for sustainable use of pesticides of the German federal government (NAP), released in 2013. There, the target primarily adresses to public authorities (e.g. authorities at Land level, official bodies active in providing advice) and/or professional associations to draw up such guidelines. The Julius Kühn-Institut provides advice to this process. Relevant associations for consumer and environment protection are involved where applicable. With a general acceptance as an essential characteristic, guidelines for important crops, groups of crops or sectors should be achieved. The scope of the German Plant Protection Act includes stored product protection as part of plant protection. Stored product protection based in this sense on plant products (e.g. grain, pulses, dried fruit, tea, raw cocoa) means a wide range of issues and possible applications. Along with the large number of applications, the number of actors involved is comparatively larger than in agriculture. Moreover, the general principles of integrated pest management according to Directive 2009/128/EC, Annex III do not fit exactly on the stored product protection sector.

In order to cope with this difficult task, the development of specific guidelines for integrated pest management and in organic farming in stored product protection sector including this publication is funded by the Federal Ministry of Food and Agriculture (BMEL) based on a decision of the Parliament of the Federal Republic of Germany via the Federal Office for Agriculture and Food (BLE) within the Federal Program on Organic Farming (BÖLN). This research program is carried out by the stored product protection group at Julius Kühn-Institute.

This presentation gives an overview of the activities in the running research program. It paints a picture of the effort to identify and bringing together all concerned groups, in detail farmer, storekeeper, retailer, pest controller and more. The framework and potential hindrance as well for generally accepted guidelines are discussed. A draft guideline containing modified general principles of IPM and special sections for important situations and commodities in stored product protection is presented. Using the storage of imported raw-cocoa as an example for a special situation, the main points in integrated stored product protection are explained.

ATTRACTION AND OVIPOSITION OF PEA WEEVIL (*BRUCHUS PISORUM* L.) ON HOST AND NON-HOST PLANTS

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Pea weevil (*Bruchus pisorum* L.) is a major pest of field pea (*Pisum sativum* L.) worldwide causing a considerable amount losses in yield and quality of the crop. The objectives of this study were to assess attraction of female and male weevils to flower of host genotypes using a Y-tube olfactometer. Furthermore, we determined oviposition preference of the weevil among host and non-host plants in no-choice and dual-choice conditions. Results of behavioral study showed that female weevils were significantly attracted to host plant floral volatile. Moreover, female insects were equally attracted to volatiles of susceptible and moderately resistant host genotypes regardless of their feeding status. Oviposition bioassay results indicate that both under no-choice and dual-choice tests, female weevils significantly prefer to oviposit on *Adet*, (which is a susceptible genotype) compared with two moderately resistant genotypes and non-host plants. The weevils laid significantly less number of eggs on non-host plants as compared to host genotypes. Morphological traits of the pod and seed might be partly attributed to preference of the weevil among test plants for ovipostion. The present study demonstrate that floral volatiles play a role in attraction of the weevil, and female weevils showed a clear preference for ovipostion to susceptible host genotype compared with moderately resistant one and non-host plants.

REQUIREMENTS FOR EFFECTIVE MATING DISRUPTION OF A LEAFHOPPER WITH VIBRATIONAL NOISE

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After the success of preliminary trials with the bioacoustic method for mating disruption of the leafhopper *Scaphoideus titanus* Ball, we set out to investigate requirements for efficiency of this method in small-scale trials. Artificially induced vibrational noise is, in principle, able to prevent mating by obscuring information about the emitter's location, identity and quality, contained in vibrational signals and necessary for mating success in leafhoppers. The next step is to examine technical issues, such as minimal amplitude and time of activation, as related to energy consumption and equipment wear. We used a pre-recorded disturbance signal, such as it is used by males of this species in rival interactions with other males, and transmitted it into plants using electromechanical transducers. We tested efficiency and limitations of the method in laboratory and semi-natural conditions, focusing on amplitude, diel pattern of activation and the method of transmitting vibrational noise to host plants of *S. titanus*. Necessary amplitude for efficient disruption was determined in laboratory trials in a simplified localization task, while diel pattern of activation and attenuation were examined in the field. As expected, hours when the disruption must be active overlap the most active periods of male calling, but it is possible to switch off the playback at least for a part of the day without losing efficiency. Attenuation, on the other hand, is proving to be a major issue with prototype transducers in the field.

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.

INNOVATIVE INTEGRATED PEST MANAGEMENT (IPM) FOR WINTER WHEAT BASED ROTATION: FIRST RESULTS OF *EX POST* ASSESSMENT OF FRENCH TRIALS AFTER ONE COMPLETE ROTATION

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Given the increase of pesticide amount in surface and ground waters and the society concern about this, innovative cropping systems taking into account farm level constraints and limiting the use of pesticides need to be proposed. Within the context of the PURE project (WP2), innovative IPM solutions were designed for winter wheat based rotations in France (Paris basin area). Three cropping systems were designed according to a gradient of pesticide-use intensity (i) current agricultural practices (CS) with a conventional use of pesticides, (ii) intermediate level of IPM (IS) with a reduction in pesticide use and (iii) advanced level of IPM (AS) where no pesticides are allowed. We used a three-step prototyping method: (1) crop successions and agricultural practices were defined for each system, (2) the prototypes underwent an *ex ante* sustainability assessment with the DEXiPM tool (Pelzer et al., 2012) and, (3) the most promising systems were tested in field trials starting in 2009. As they have all completed their first rotation in 2014, the experimental results can thus be analysed according to the pesticide use (frequency treatment indicator, FTI), environmental pesticide impacts (Synops tool), different environmental components, yield and economic margins. This enables an *ex post* reassessment of the system's sustainability.

The IS and AS differ from the CS by their high diversity of crops and long rotations, the regular use of mechanical weeding, and the choice of seeding dates, densities and varieties in order to reduce pesticide uses. For the *ex ante* assessment, FTI and environmental impacts of the prototypes are ranked according to the gradient of pesticide use: AS < IS < CS. All systems achieved a "medium" score of overall sustainability, obtained by different combinations of performances on the three sustainability pillars. For the *ex post* assessment, only preliminary experimental results are available because all crops of the AS are not harvested. However, the three systems gave same ranking, in terms of FTI and environmental impacts, than those of the prototypes. In the IS, yields are higher and pesticides costs lower than expected, leading to higher production value and gross margin. In term of overall sustainability, the CS and IS both achieve "medium" score as expected. The completed assessment will allow a more thorough analysis. The results will be discussed from both an agronomic and a methodological point of view in order to answer the following questions: (i) Is it possible to reach simultaneously the objectives set regarding pesticide use reduction and regarding economic gains? (ii) Are all the agricultural practices used in these cropping systems innovative?

CURRENT SITUATION AND FUTURE PLANS FOR IPM IN TURKEY 26

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Turkey produces more than 60 kind of agricultural crops including cold, warm and subtropical crops. Approximately up to 400 harmful organisms are present and some of them have economic importance.
The first IPM study was conducted in 1970 based on crop (cotton) and continued on apple and hazelnut in 1972. In the following years, IPM studies on wheat, tobacco, grapevine, citrus, peach and cabbage were carried out. By additional of potato, vegetables and ornamental plants (grown undercover), maize, olive, cherry, pistachio and apricot, the number of IPM programmes have reached to 16 in 1995. They were updated and published in 2011.
Apple is the most widespread crop in conducted IPM studies in the country. Forecasting studies against Codling moth and Apple scab have been carried out in all apple cultivation areas of Turkey for thirty years. These studies are being carried on 6.7 million on apple trees by 154 stations in 31 provinces. The other important crop is grapevine, carried out in IPM programmes. Forecasting studies against grapevine berry moth and downy mildew have been carried out in all vineyard cultivated areas of Turkey for thirty years. These studies are being carried on 1.5 million decares vineyard by 49 stations in 20 provinces.
IPM Programmes are carried out with the cooperation of the Research Institutes, extension services, farmer unions and farmers. They mainly cover alternative control measures. Rather than chemical control methods, alternative control measurements such as biological control, biotechnical methods, resistant varieties, genetically control, mechanical and physical control and the cultural measurements have priority in the IPM technical guides. Success of IPM is evaluated by mitigation of pesticide uses.
Future plans for IPM in Turkey; Development of chemical-alternative methods, development of control methods suitable to IPM, improvement of forecasting methods, improvement of present forecasting methods by simulation, development of biological control methods against key pests, number of IPM programme is planned to be increased.

SUSTAINABLE PESTICIDE USAGE IN TURKEY 27

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Crop production products have the potential harm to the environment and human health if not used safely and correctly. Use of pesticides without risking food production and reduction of pesticide risks seem only possible by making innovations in the agricultural production systems. Several strategies are in force in Turkey for mitigation pesticide use.

The country gives priority to developing alternative methods to decrease pesticide use projects about integrated pest management (IPM), biotechnical and biological control. The aim of research studies carried out in the country is protection of human health and environment and research on new methods and techniques as alternatives for chemical control. Four hundred sixty projects on plant health in the last decade were finalized. 37% of these projects are on reduction of pesticide use including alternative methods. These projects were on plant protection products excluding pesticides 22%, biological control 18%, IPM 14%, pesticide residues 8%, pesticide equipment 8%, toxicology 5%, biotechnical control 5%, forecasting 3% and others 15%.

Plant protection applications carried out in Turkey is aim to disseminate IPM, biological and biotechnical control. The projects about IPM began in Turkey in the 1970s. At the beginning of 1980s, we started to share the findings of IPM studies with farmers and they started to put them to use. Technical guidelines for IPM have been prepared on 16 crops and have been put into practice.

Biological control has priorities in plant protection policies and strategies in Turkey. The classical biological control studies in Turkey were started in 1912 and an increasing importance has been given to them since 1970s. Plant Protection Research Institute was reorganized as Biological Control Research Station in 2011. Biological Control Centre will be opened under Biological Control Research Station in Adana. Its purposes are; to increase biological control opportunities, to reduce pesticide use, to protect human health, environment and natural balance. Biological and biotechnical control for reducing pesticide use has been promoted for four years.

Many important directives have been put into force to provide reliable food from field to fork, solve pesticide residue problem in fruits and vegetables faced in exporting and also domestic consumption, and to protect flora, fauna, environment and human health. These studies have prevented inflation of pesticide use in the last decade.

DEXIPM GRAPEVINE, A MULTIPLE CRITERIA MODEL FOR SUSTAINABILITY ASSESSMENT OF GRAPEVINE CROP PROTECTION STRATEGIES 28

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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 agroecosystems 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 the high sensivity of grapevine to pests and diseases.

DEPHY: A LARGE NETWORK TO DEMONSTRATE CROPPING SYSTEMS WITH A LOW RELIANCE ON PESTICIDE

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The DEPHY network was launched in 2010–2012 as a major initiative of the action plan ECOPHYTO, which was put forward by the Ministry of Agriculture to reduce the reliance of the French agriculture upon pesticides. The network is basically based on 1900 farmers who volunteered to be involved in demonstrating cropping systems with low pesticide inputs. It is composed of about 190 groups of farms distributed over the whole national area, representing six agricultural sectors, namely 'arable crops', 'vineyards', 'orchards', 'vegetables', 'horticulture' and 'tropical crops'. Each group is coordinated by a 'Network Engineer' from a professional organization, i.e. either a local agricultural extension service ('Chambre d'Agriculture', 'CIVAM') or an agricultural cooperative. Each Network Engineer is in charge of (i) animating his group, (ii) elaborating a project with each farmer to change cultural practices and reduce pesticide inputs, (iii) accompanying the farmers in their crop management, (iv) organizing local communications towards farmers outside the network , and (v) collect data to describe cropping systems and evaluate their sustainability. In addition to this farm network (DEPHY-Farm), DEPHY also includes 170 experimental sites (DEPHY-Expe), mostly in experimental stations, where research and extension services test cropping systems based on innovative and/or more risky strategies. The whole network is coordinated at the national scale by a group defining the working methods that are shared in the network, and organizing and analyzing the data for a national communication.

The objective of the DEPHY network is to demonstrate that it is possible to use low amounts of pesticides while maintaining a good profitability and overall sustainability, so as to inspire other farmers and drag them toward more sustainable practices. The level of pesticide use is evaluated at the cropping system level and is compared to a local reference of Treatment Frequency Index. About 30% of the farmers already used little amount of pesticide when they joined the network, and therefore already demonstrate that it is possible to produce with reduced use of pesticide, at least in their specific region and agricultural context. The other farmers were more representative of local crop management when they joined the network, but are expected to change significantly their cropping system and their decision making with the help of the network dynamic, and this is considered a powerful pathway to convince that changing is possible also in agricultural contexts where an heavy reliance upon pesticide is currently the standard dominating model.

The network organizes the analysis of the produced data to (i) identify cropping systems combining low pesticide input and high profitability (e.g. 24% of cropping systems at the beginning of the farm network in the sector of 'arable crops'), (ii) describe the details of those interesting systems (context, management options, decision making process, and assessments of a range of sustainability indicators : productivity, profitability, energy efficiency, workload requirements, …), (iii) identify common features of those systems, both in term of production situation and of strategic management options, (iv) identify production situations where combining low pesticide use with high profitability remains rare in the network. Some early results of this unique and powerful network are presented.

The DEPHY network is driven by the French Ministry of Agriculture and is funded by ONEMA.

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.

RESIDUE ANALYSIS OF CANDIDATE PESTICIDES FOR PROTECTION OF MINOR CROPS APPLYING GC-MS/MS AND UPLC-MS/MS 33

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National authorities are responsible for enforcement of pesticide legislation following Regulation 1107/2009 and Directive 2009/128/EC while professional users are responsible for proper application of plant protection products, thus ensuring that treated crops will be free of excessive pesticide residues. We will present application of new pesticide residue analytical methods as monitoring tools to confirm safe and proper use of candidate pesticides having potential to be applied on selected minor crops to control pests, weeds and diseases affecting the production of these crops.

The main objective of our work was to develop, validate and apply to real samples a new approach to determination of pesticides in minor crops of high chlorophyll content. We focused on such crops as lupin, white mustard, soya bean, field bean and sunflower. We selected 25 candidate pesticides of the pesticides already approved for use on other crops in Poland (i.e. major crops). For sample preparation, we used the QuEChERS procedure with some modifications. Because green matrices, high in chlorophyll, represent a particular challenge due to massive amounts of coextractives, we employed a new type of sorbent, known as ChloroFiltr, to reduce chlorophyll from the extracts. The final determination was carried out by concurrent analysis using gas chromatography and ultra-performance liquid chromatography coupled to tandem quadrupole mass spectrometry (GC-MS/MS and UPLC-MS/MS).

Once the method conditions were established, the method was subjected to comprehensive validation study which was carried out on lupin, white mustard and sorghum. The overall recoveries at the three spiking levels of 0.01, 0.05 and 0.5 mg/kg were in the range between 68 and 120% (98% on average) and 72 – 104% (93% on average) with relative standard deviation (RSD) values between 2 and 19% (7% on average), and 3 and 16% (6% on average) by GC-MS/MS and UPLC-MS/MS technique, respectively. Quantification was always done by using matrix-matched standards to achieve accurate results [1].

Up to now, the proposed method has been successfully used to study the dissipation patterns of pesticides after application on lupin, white mustard, soya bean, sunflower and field bean in experimental plot trials conducted in Poland. Our results reassured the correct pre-harvest intervals since, in most cases, the pesticides completely disappeared on the treated plants before harvest. We can conclude that the proposed plant protection products can be safely used on the studied minor crops, without the risk of leaving problematic pesticide residues.

LEMON GRASS ESSENTIAL OIL AS A NATURAL FOOD PRESERVATION: INVESTIGATION ON VOLATILE COMPOUNDS, *IN VITRO* ANTIFUNGAL ACTIVITY AND CONTROL OF *SACCHAROMYCES CEREVISIAE* IN REAL FRUIT JUICES (ORANGINA) 34

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In spite of the use of all available means of food protection, spoilage of foods is still a major problem in different parts of the world. Yeasts and filamentous fungi are widely distributed in nature and are responsible for the microbiological spoilage of an extensive range of food. Alternative sources of safe, effective and acceptable natural preservatives need to be explored, such as essential oils. Natural antimicrobials can be used alone or in combination with other novel preservation technologies to facilitate the replacement of traditional approaches in food preservation.

The antifungal activity of Algerian Lemon grass (*Cymbopogon citratus*) essential oil (LGEO) was evaluated against several food spoiling yeasts and molds through disc diffusion and vapour diffusion methods.

The chemical profile of EO, characterized through Gas Chromatography-Mass Spectrometry (GC–MS) analysis, revealed geranial (42.2%) and neral (31.5%) as major components.

LGEO exhibited promising antifungal effect against *Candida albicans*, *C. tropicalis* and *Aspergillus niger*, with different inhibition zone diameters (IZD) (35–90 mm). Significantly, higher anti-*Candida* activity was observed in the vapor phase. *C. albicans* and *C. tropicalis* were inhibited completely by the LGEO vapors at 60 µL per disc. Moreover, the zone of inhibition increased with increasing oil volume.

Furthermore, the anti-yeast efficacy of LGEO oil alone and in combination with thermal treatment was evaluated in a real food system (Orangina fruit juices). The samples treated with a combination of LGEO at 0.2% and 0.16% and thermal treatment enhanced the reduction viability. Present results established the superior performance of integrated (thermal-LGEO) treatment over the individual exposure (LGEO alone) for Orangina juice preservation. Results confirmed the effectiveness of LGEO in providing an immediate and significant protection of Orangina juice to yeast proliferation.

SOLVENT FREE MICROWAVE EXTRACTION: AN ECO-FRIENDLY AND RAPID PROCESS FOR GREEN ISOLATION OF ESSENTIAL OIL FROM LEMON GRASS

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Since the Lemon grass (*Cymbopogon citratus* (DC.) Stapf) essential oil (LGEO) has been used widely as pharmaceutical, nutraceutical and antimicrobial agent in the food industry, it is necessary to find the most suitable method for the improvement of its quality.

Solvent-free microwave extraction (SFME) is a combination of dry distillation and microwave heating, executed without added any solvent. SFME of Lemon grass oil was compared with conventional extraction, Hydrodistillation (HD), in terms of process time, yield, chemical composition and physical properties.

SFME is clearly quicker than conventional HD. An extraction time of 15 min with SFME provides yields (0.6%) comparable to those obtained after 120 min by means of HD. The chemical composition of these oils was investigated by Gas Chromatography-Mass Spectrometry and revealed the presence of 23 and 18 compounds in the essential oils obtained through HD and SFME, respectively. The main components of both oils obtained by HD and SFME were geranial (46.16–42.59%) followed by neral (31.52–29.94%) and myrcene (7.45–10.5%), respectively. Substantially higher amounts of oxygenated monoterpenes (77.73%) were present in SFME oil in comparison with HD (73.97%). This study could be considered as the first report on the chemical composition of LGEO obtained by SFME. No significant differences were obtained in the physical and chemical properties of volatile oils.

SFME is a green technology and appears as a promising alternative for the extraction of essential oils from natural products.

THE MODEL PROJECT "DEMONSTRATION FARMS FOR INTEGRATED PEST MANAGEMENT" – A SUITABLE INSTRUMENT FOR IPM IMPLEMENTATION IN GERMANY

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The German model project "Demonstration Farms for Integrated Pest Management" is part of the German National Action Plan on Sustainable Use of Plant Protection Products. Its objective is the implementation and demonstration of integrated pest management (IPM) measures into practice.

Between 2011 and 2014 in total 66 agricultural farms from different growing regions all over Germany have been selected to become demonstration farms and participate in the project for a period of 5 years. The farms represent major production sectors such as apple growing, viticulture, arable cropping, vegetable growing and hop production. The project aims to introduce innovative findings and suitable methods of integrated plant protection into practice, and demonstrate this to other farmers, advisors as well as to the public.

Specific requirements of IPM based on the general principles of IPM (Annex III of Directive 2009/128/EC) were defined in project-related IPM guidelines formulated for each production sector. In order to ensure a high standard of IPM implementation, demonstration farms receive intense support and supervision by plant protection experts and hired advisors from the plant protection services of the federal states. They provide for comprehensive assistance when introducing new procedures. Furthermore, they are responsible for monitoring of crops, pests and diseases and data collection. Technical advice, monitoring systems and modeling of plant pathogen/pest systems (prognosis, decision-support-systems) is provided by the Central Institution for Decision Support Systems in Crop Protection (ZEPP). Thus, demonstration farms receive IPM-information and excellent advice tailored to their needs which by far exceeds the usual standard (on average one advisor assists five farms). Additionally, the farms receive small expense allowances and monetary compensation in case of yield reductions due to IPM implementation strategies.

The Julius Kühn-Institute (JKI) as a research institution coordinates the overall network and supports activities of the involved plant protection services. Data processing and analysis (e. g. for treatment frequency, risk indicators, non-chemical measures or expenditures for monitoring) as well as interpretation and discussion of results is also part of JKI's responsibility.

Knowledge transfer and public relation work are key objectives of the project. The demonstration farms are encouraged to organise each year a farm day with field seminars and on-site demonstrations to motivate other farms within their region to adopt the demonstrated IPM procedures. The project website introduces the participating farms and informs about the project in general and its results (http://demo-ips.jki.bund.de/).

The work is financially supported by the German Federal Ministry of Food and Agriculture (BMEL) through the Federal Agency for Agriculture and Food (BLE), grant number 2810MD001.

CROP- OR SECTOR SPECIFIC IPM GUIDELINES USED IN THE MODEL PROJECT "DEMONSTRATION FARMS FOR INTEGRATED PEST MANAGEMENT" 37

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The German model project "Demonstration Farms for Integrated Pest Management" is part of the German National Action Plan on Sustainable Use of Plant Protection Products. Its objective is the implementation and demonstration of integrated pest management (IPM) measures into practice.
In total 66 agricultural farms representing different production sectors (apple growing, viticulture, arable cropping, vegetable growing, hop production) and growing regions all over Germany participate in the project for a period of 5 years. They implement the latest findings and suitable methods of integrated plant protection into practice and demonstrate them to other farmers and advisors as well as to the public with public relations work (e. g. field seminars, open farm days).
The project-specific requirements of IPM based on the general principles of IPM (Annex III of Directive 2009/128/EC) were defined in IPM guidelines formulated for each production sector. They have been specifically drafted for the demonstration farms in cooperation with experts from the plant protection services of the federal states. So far, project-related IPM guidelines are available for arable crops (sector), apple growing, viticulture and vegetable growing (cabbage, carrots). They can be downloaded from the project website in German language (http://demo-ips.jki.bund.de/).

Each guideline is divided into six chapters:

I. availability and use of professional information on IPM
II. preventive measures
III. protection and enhancement of important beneficial organisms
IV. monitoring, forecasting systems and tools for decision making
V. use of non-chemical and chemical plant protection measures
VI. record keeping and check of success

Within these chapters, which follow the structure of the general principles of IPM, about 20 requirements have been defined. These requirements go beyond the baseline of the eight IPM principles and describe all available and feasible IPM techniques for the specific sector or crop. This includes crop rotation, sowing date, use of resistant varieties, measures for enhancement of natural control, pest monitoring and use of tools for decision-making (threshold values, forecast models) as well as use of non-chemical measures and compliance with the necessary minimum of pesticide use.
Our experiences so far show, the implementation of IPM guidelines on demonstration farms is possible and the farms are able to fulfil the majority of requirements, provided that they are supported by the state advisory service. A checklist and a scoring system have been developed in order to assess the progress of IPM implementation on the basis of IPM guidelines on the demonstration farms.
The work is financially supported by the German Federal Ministry of Food and Agriculture (BMEL) through the Federal Agency for Agriculture and Food (BLE), grant number 2810MD001.

CHECKLISTS AS A TOOL FOR DETERMINING THE STATE OF IMPLEMENTATION OF JKI-GUIDELINES FOR INTEGRATED PEST MANAGEMENT OF THE PROJECT "DEMONSTRATION FARMS FOR INTEGRATED PEST MANAGEMENT" 38

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Checklists and a scoring system were developed to evaluate the implementation of integrated pest management (IPM) on the demonstration farms for integrated pest management (IPM) in Germany and based on the drafted IPM guidelines developed by JKI for apple, viticulture and arable cropping, which follow the structure of the general principles of IPM published in Annex III of Directive 2009/128/EC.

This poster reports on the approach in arable cropping. First, IPM guidelines containing 20 requirements were developed for arable cropping. The checklist based on these requirements. Each requirement was described in detail to ensure an evaluation in terms of the degree of implementation of this given requirement. The described requirements include the use of professional information on IPM, crop rotation, measures for enhancement of natural control, pest monitoring and compliance with necessary minimum of pesticide use by including data on reference farms, etc. In each case, a table can be used for comments, and the degree of implementation is assessed using a scale of 0 to 3, 4 or 6 scores, depending on the importance of the requirement within the IPM concept.

The assessment was done by experts from the state plant protection services in collaboration with the consultants of the states mentioned above. If they determined that implementation did not meet the requirements of the IPM guidelines, the farm received a score of 0 or, at most, 1 or 0 to 2. If implementation performance exhibited room for improvement, the score could be 2, 2 to 3 or 3 to 4, and if performance fully meets the special requirement of the IPM guideline, the maximum score (3, 4 or 5 to 6) was possible. Thus, a total of 80 points could be achieved.

This approach allowed identification of shortcomings in IPM implantation in arable cropping, e. g., insufficient use of fungus-resistant cereal varieties or of non-chemical crop protection measures.

In 2011 (before the project started) the demonstration farms for IPS reached 62 to 83% of the maximum achievable scores. The evaluation of the first project year showed an increase of 2–8% to 70 to 85% of the maximum possible scores. In the second year of the project (2013), a further increase could be achieved and thus amounted to 70 to 90%.

The current discussion relates to what percentage of the maximum achievable scores must be obtained to fulfil an adequate level of IPM. Further development of the IPM scoring system considering bonus points for certain cultural and non-chemical control measures within the context of special environmental protection programs is discussed.

MULTI-ANNUAL RESULTS OF DATA OF THE DEMONSTRATIONS FARMS FOR INTEGRATED PEST MANAGEMENT IN ARABLE CROPS IN MECKLENBURG – WESTERN POMERANIA IN COMPARISON WITH FARMS OF REFERENCE FARMS NETWORK FOR PLANT PROTECTION 39

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The project "Demonstration farms for integrated pest management (DIPM)" was established in Mecklenburg-Western Pomerania with five farms in arable crops in 2011. These typical farms for this region demonstrate the IPM with an intensive support by state advisory service and a special consultant.
In 3 winter wheat (WW), winter barley (WB) and winter oilseed rape (WOR) fields per farm the pesticide use and monitoring expenses by the consultant were collected in the years 2010 and 2011 (before the project started) and in the first years of the project (2012 and 2013). These multi-year data at field level (n=15 fields per year) were compared with the data of the farms of the reference farms network for plant protection (RF). Finally, the environmental risk by the pesticide use has been analyzed for aquatic and terrestrial organisms by the model SYNOPS-GIS. The results showed that the treatment frequency index (TFI) in winter wheat, winter barley and winter oilseed rape during were 13%, 25% or 18% significantly lower in depending on the year in the DIPM the project period (2012–2013) in comparison to the RF (Tab.). The reduction of the TFI was mainly achieved in fungicide (WW, WB) and insecticide use (WW, WB, WOR). This was achieved by the intensive monitoring by the special consultant.

Tab. Pesticide use intensity (TFI) in winter wheat, winter barley and winter oilseed rape in DIPM and RF in Mecklenburg-Western Pomerania in 2010 to 2013

		Before project started				Project period			
		2010		2011		2012		2013	
		DIPM	RF	DIPM	RF	DIPM	RF	DIPM	RF
WW	$\bar{x}$	6,4	6,7	6	6,7	4,7	5,4	5,4	6,9
	s	1,9	1,3	1,2	1,4	1,1	1,7	1,4	1,8
WB	$\bar{x}$	3,8	4,1	3,9	3,8	3,7	4,7	3,5	4,9
	s	1,2	0,6	1,1	0,9	1	1,3	0,8	1,1
WOR	$\bar{x}$	6,1	6,6	6,8	8,1	5,3	6,7	6,1	7,2
	s	1,4	1,9	1,3	0,9	1,5	0,8	1	1,2

The reduction of pesticide use was mainly based on intensive field monitoring by the consultant and the state advisors supporting of the managers of the DIPM. The first results from MV show that monitoring activities for the implementation of integrated pest management in arable crops in the amount of 2.8 h in winter wheat, 1.8 h in winter barley and 3.1 h in winter oilseed rape were needed.
In 2012, the chronic aquatic risk was medium in the two networks but twice as high in the DIPM as the RF. In 2013, the chronic aquatic risk was approximately at the same level in both networks and lower than 2012. The analysis of chronic terrestrial risk (earthworm) exhibited and networks at a low risk in both years. It should be noted that the chronic aquatic and terrestrial (earthworm) risk was strongly determined by the TFI and the choice of pesticides. The work is financially supported by the German Federal Ministry of Food and Agriculture (BMEL) through the Federal Agency for Agriculture and Food (BLE), grant number 2810MD001.

THE DEVELOPMENT OF INTEGRATED PLANT PROTECTION IN POLAND 40

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In 1964 for the first time in Polish bibliography the conception of integrated pest control was presented and a year later the results of introductory research of integrated control of sugar beet pests was published. At the same time several research programmes were undertaken in order to determine the role of natural factors in the reduction of pest numerousness as well as to increase the participation of biological and other non-chemical methods in crop protection. On the May 18th 1970 Polish government established the Act of the Council of the Prime Minister No 64/70 regarding organising research on toxicology and safe application of pesticides and control of residues in food and environment of human existence.
Positive results of this Act were following:

- withdrawing of DDT, mercury dressing and other hazardous substances,
- limitation until withdrawal of application of dust forms of plant protection products and organising research systems on residues of plant protection products.

In the same time the system of plant protection products registration was introduced in Poland and also on the territory of the whole country registration of occurrence and density of most important pests was organised. Based on above mentioned activities as well as taking into account the obtained results of experiments elaboration and implementation to the practise of integrated plant protection products took place: in glasshouses (1984), orchards and agriculture crops (winter wheat – 1992, winter rape – 1994).
Important for the development of integrated plant protection was voted by Polish Parliament in 2003 New Plant Protection Act were in the article 68 is stated: "The treatments with the use of plant protection products shall be carried out taking into account, in the first place, biological, agrotechnical and breeding methods or integrated control".
From the end of 90's of the last century the integrated production technology has been implemented to the practice and presently State Inspection of Plant Protection and Seed Production is responsible for the certification of such technology.
Summarising present situation it could be said that there are a number of positive factors which effect the development of integrated plant protection and production as following:

- Polish legislation,
- obtained research results and well-prepared scientists,
- pressure of ecological groups and consumers of agriculture products,
- world trends in plant protection,
- achievements in the production of plant protection products and sprayers.

OFFICIAL TESTING OF PESTICIDE RESIDUES IN POLISH CROPS IN 2011–2013

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Since 1996 Institute of Plant Protection – National Research Institute (IPP – NRI) have been performing official testing of pesticide residues in crop samples taken at the primary production stage for Main Inspectorate of Plant Health and Seed Inspection, within the supervision framework of the trade turnover and application of protection plant products. The purpose of the studies is to check whether plant protection products are used by producers in compliance with Plant Protection Regulation requirements.

In 2011–2013, the studies were conducted within the multi-annual programme "Protection of cultivated plants with the consideration of food safety, reduction of yield losses and threat to humans, livestock and the environment" financed by Minister of Agriculture and Rural Development. The research comprised the determination of pesticide residues in 3583 samples of 62 commodities randomly collected from domestic farms by inspectors of Plant Health and Seed Inspection. Fruit and vegetables were the majority of the tested products (75.1%). Overall, the residues of 274 compounds were sought in the samples. Methods fulfilling the requirements of the SANCO/12495/2011 guideline, in particular, the multi-residue methods based on gas and liquid chromatography (GC/MS/MS, GC/ECD/NPD, LC/MS/MS, UPLC/UV/PDA) were applied in the studies.

Pesticide residues were found in 23.9% samples. In total, residues of 78 pesticides were detected in all control products. Multiple residues in the same sample, residues of two or more pesticides were found in 335 samples, corresponding to 9.4% of the samples analysed. Pesticide residues were detected in fruit (43.1%), oilseeds (26.7%), vegetables (21.7%) and sugar plants (14.6%). They were most often found in samples of gooseberries (72.2%), apples (52.9%), carrots (49.3%), tomatoes (47.3%), strawberries (46.3%), currants (45.8%), pears (43.8%) and celeriac (40,4%). The most frequently detected pesticides were bupirimate in gooseberries (55.6%), difenoconazole in gooseberries (38.6%), dithiocarbamates in currants (35.2%), chlorpyrifos in carrots (34.3%), dithiocarbamates in potatoes (33.9%) and captan in pears (31.3%). In 1.1% of the samples, the EU MRLs were exceeded for one or two pesticides, while in 4.0% of analysed samples the residues of unauthorised plant protection products were observed.

ESTIMATION OF DIETARY EXPOSURE TO PESTICIDE RESIDUES IN POLISH CROPS

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One of the most important factors influencing the human development and health condition is nutrition habit. The quality of food including first of all health safety as well as usable attributes of products often decides what is the consumer choice. Safe food should be characterized by both, adequate nutritive value and the tolerably low content of substances which presence could be a risk and threat for health, e.g. pesticide residues. The aim of the study was to estimate long-term and short-term intake of pesticide residues in Polish fruit and vegetables in 2011–2013. The estimation of dietary exposure was based on pesticide residue data from official testings of 62 domestic crops at the stage of primary production carried out by 5 laboratories of Institute of Plant Protection – National Research Institute and on British food consumption data.
Estimated dietary intake examples have shown that consumers' chronic dietary exposure to pesticide residues in Polish commodity was as follows:

- in apples, where the most pesticide residues were found, the long-term exposures, expressed in percent of the ADI, for a total of all compounds were for adults and for toddlers respectively: in 2011 – 12.5% and 69.1%; in 2012 – 3.4% and 18.8%; in 2013 – 7.0% and 38.7%.
- in 61 other products, the long-term exposures (in percent of the ADI) for a total of all compounds were for adults and for toddlers below 10%.

The maximum acute dietary exposures in percent of the ARfD were for adults and for toddlers respectively: in 2011 – 12.0% and 57.6%; in 2012 – 21.6% and 85.6%; in 2013 – 57.1% and 94.7%.
The results show that Polish fruit and vegetables are relatively safe in long- as well as in short-term nutrition.

THE INFLUENCE OF GREY MOULD (*BOTRYTIS CINEREA*) ON DEVELOPMENT OF THE SPIDER MITE POPULATION AND ITS NATURAL ENEMIES IN TOMATO GREENHOUSE CROPS

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Several species of spider mites occur on ornamental plants and vegetables cultivated in greenhouses. The most important are: the two-spotted spider mite *Tetranychus urticae* (Koch.) and red spider mite *Tetranychus cinnabarinus* (Boisd.).
According to the Polish Directives, biological methods should be used prior to any application of chemical products. Biological control is a priority in plant protection, particularly for vegetable crops in greenhouses. Biological agents such as macroorganisms are not subject to registration requirements in Poland. Thus, there are natural enemies commercially available in Poland. A great many mites in the family *Phytoseiidae* are predators of spider mites. In addition to the *Phytoseiidae* family of mites, Integrated Pest Management (IPM) is often used in greenhouses vegetable crops, mainly in tomato.
The aim of greenhouse studies was to determine the efficacy of the predators: *M. melanotoma*, *A. limonicus* and *A. andersoni* for the control of red spider mite (*Tetranychus urticae*), as well as the effect of grey mould on the pest level and its natural enemies in tomato greenhouse crops. A series of experiments on the efficacy of natural enemies (*Macrolophus melanotoma, Amblyseius andersoni, Amblydromalus limonicus*) against spider mites in greenhouse grown tomatoes were carried out under the laboratory and greenhouse conditions. It was shown a high efficacy (82%) of the joint use of two predatory species *M. melanotoma* and *A. andersoni* in reducing the population level of the red spider mite (*Tetranychus urticae*). Both predatory mite species can be applied jointly without any advertise effects (a phenomenon of neutralism). The joint use of the species *A. limonicus* and *A. andersoni* caused a high mortality (72%) of the pest. However, the efficacy of this treatment was not statistically different as compared to the treatment with a separate use of the predator *A. limonicus*. The result of the studies on joint use of *A. limonicus* and *A. andersoni* revealed a phenomenon of interspecies competitiveness, and as a consequence the species *A. limonicus* dominated. Therefore, their joint application should not be recommended as a biocontrol agent in integrated plant protection programmes. The greatest increase in the number of spider mite was shown in all treatments with tomato plants infected by grey mould (*Botrytis* cinerea). The number of spider mites increased by fivefold in the treatments with tomato plants infected by grey mould (*Botritis cinerea*), and all those treatments showed a lowered efficacy of the applied predators *A. limonicus* and *A. andersoni* in reducing the pest level. The efficacy of the predatory mite species *M. melatonoma* against the red spider mite was not affected by the infection of tomato plants with grey mould. The pathogen didn't influence on efficacy of *M. melanotoma* in controlling of spider mites.

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007–2013) under the grant agreement n°265865-PURE

THE ROLE OF ADJUVANTS IN THE EFFICACY OF ENTOMOPATHOGENIC FUNGI: *I. FUMOSOROSEA* AND *L. LECANII* IN CONTROLLING WHITEFLY (*TRIALEURODES VAPORARIORUM* WESTWOOD) 44

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The effectiveness of entomopathogenic fungi applied foliarly depends on different factors in open field and in greenhouse crops. The optimal level of relative humidity for tomato is lower than needed for infection caused by fungi. Several species of entomopathogenic fungi are known, which are used in controlling whitefly in greenhouse tomato crops. The rich waxes on the surface of the insect significantly hinder its wetting during spraying an aqueous suspension. The possibility of improving the effectiveness of entomopatogens is seen in modifying the suspension properties. The aim of the study was to evaluate the role of adjuvants (humectant and surfactant) in the effectiveness of *L. lecanii* and *I. fumosorosea* in controlling whitefly (*T. vaporariorum*).
In the studies were used $CaCl_2$, glycerin like humectants and cocoglucoside (Glucopon 650 EC – BASF) and a commercial adjuvant Addit (Koppert) that acted as wetting agent. Under the microscope the diametr of a droplet on leaf and parafilm were measured. The wetting of nymph on the surface of the liquid was also evaluated. Biological tests were carried out with *I. fumosorosea* and *L. lecanii* at a concentration of $5 \cdot 10^6$ and $1 \cdot 10^7$ in a mixture with adjuvants. Scanning (SEM) observations showing the deposit of substances and the development of fungus after application of drops of liquid on individual insects were made. The germination of spores on PDA culture medium was rated. Spraying indicators for leaf and parafilm under conditions corresponding to the application of spore suspensions were also taken.
Addition an adjuvant to a suspension of the entomopathogenic fungi increased mortality of whitefly. Insect mortality was the highest after application of a liquid containing cocoglucoside and humectant. When *I. fumosorosea* was applied, the addition of $CaCl_2$ and cocoglucoside increased mortality more than cocoglucoside and glycerin. When *L. lecanii* was applied insect mortality didn't depended on the type of the humectant. Droplet spreading was not significantly differentiated on tomato leaf and parafilm when liquid mixtures contained cocoglucoside and Addit. Similarly, the wetting of insects on the surface of the liquid did not differ. While the best humectant was $CaCl_2$, drying time of droplets did not differ from glycerol. The spores germination ability after addition of cocglucoside and humectants did not differ of spore only in water. Deposit of substances on the surface of nymph differed morphologically. It is possible that $CaCl_2$ could cause greater stress of insects than glycerol. Cocoglucoside caused significant mortality of insects even without fungal insecticide. Cocoglucoside caused more than a double coverage of sprayed surface compared to water. The mortality of whitefly depended on the coverage of leaf and insects, fungal pathogenicity and physical impact of adjuvants on insects.

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STUDY ON CONTAINERS DISPOSAL OF PESTICIDES BY THE FARMERS IN THE FEDERAL CAPITAL TERRITORY ABUJA, NIGERIA 45

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Many farming communities in Gwagalada area council of the Federal Capital Territory were visited to ascertain the best practices involve in the disposal of various Empty pesticides containers being use by the farmers and a semi structured questionnaire were distributed and analyzed , pictures were also taken to ascertain and support the findings and observation were made the Findings shows that there is no formal ways of disposal , empty containers were throw within the farms and some of the containers are being use for domestic purposes. This paper therefore recommends for capacity building for the best practices to avoid hazard that may cause to man, animals and valuable plants and the recommendation on the burying of the containers.

IN VITRO STUDIES ON THE POTENTIAL FOR BIOLOGICAL CONTROL OF *RHIZOCTONIA SOLANI* ON PEPPER BY BINUCLEATE *RHIZOCTONIA* 46

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Pepper (*Capsicum annuum* L.) belongs to the family Solanaceae, which is an important group of vegetables cultivated extensively in Turkey and also widely cultivated in almost every country of the world. *Rhizoctonia solani* is associated with root and hypocotyl rot of pepper. Protection against root and hypocotyl rot diseases caused by *R. solani* has been reported in many crops treated with nonpathogenic binucleate Rhizoctonia (BNR). Three isolates of BNR from pepper were evaluated for their in vitro for control of *R. solani* anastomosis groups AG-2 type 1 (B418), AG-4 (B92) and AG-6 (B93). BNR isolates B82 (AG-K), B84 (AG-A) and B360 (AG-G) provided protection of 76,7 to 100% against isolate B418 of AG-2 type 1 and 11,6 to 23,3 protection against isolate B92 of AG-4. The BNR isolates did not provide protection to the pepper (cv. Demre sivrisi) seedling when tested against B93 (AG-6). The water agar method was useful for evaluating the potential of the non-pathogenic BNR as biocontrol agents. These BNR isolates may have potential use in management of *R. solani* in pepper, but will require rigorous testing under greenhouse and field conditions.

The work was supported by the Ministry of Food, Agriculture and Livestock, the General Directorate of Agricultural Research and Policies (TAGEM), Project No. TAGEM-BS-07/10-01/02-02, and the Scientific Research Fund of Atatürk University, Grant No. 2007/25.

LABORATORY TESTING OF ENTOMOPATHOGENIC OR INSECT ASSOCIATED FUNGI FOR THE CONTROL OF CABBAGE FLEA BEETLES (*PHYLLOTRETA* SPP.)

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Cabbage flea beetles of the genus *Phyllotreta* (CFB) present an increasing problem specifically in Slovenia and have the potential to even overshadow pest significance of the *Delia radicum* cabbage root fly that is considered the major threat to brassica crops in Europe. Due to new regulations, integrated pest management strategies are mandatory in the EU since 1st January 2014. In the framework of the project PURE, such strategies involving the biological control against CFB with entomopathogenic or insect-associated fungi were explored in *in-vitro* laboratory bioassays. Experimental systems consisted of a 450 ml plastic cup into which a fresh leaf of kale and 10 field-collected *Phyllotreta* spp. beetles were added. The pot cover and pot base was perforated to insure air circulation. Our test fungi were isolated from various substrata in Slovenia and included *Metarhizium anisopliae*, *M. brunneum*, *Clonostachys rosea* and *Trichoderma atroviride*. Each species was represented by a single isolate. *Beauveria bassiana* from product Naturalis served as a positive reference strain in the experiments. Conidial suspensions were prepared in 0.1% Tween 80 at a concentration of $1x10^8$ conidia ml^{-1} and sprayed three times on the upper and lower side of kale leaves using a hand-held 10 mL dispenser. Naturalis was similarly applied using the recommended concentration of 0.05% and the negative control consisted of 0.1% Tween 80. Four replicates per treatment were made. The experiment was repeated twice independently. Experiments were evaluated after 7 and 14 days. The number of living, dead and mycotic beetles and the kale leaf feeding rate was recorded. All fungal strains tested and the product Naturalis were infective to CFB imagos and significantly increased the mortality rate already after 7 days. Abbott's corrected mortality at day 14 ranged from 31.6±5.5 to 84.7±6.8%. *Metarhizium anisopliae*, *M. brunneum* and *B. bassiana* (product Naturalis) significantly reduced also the CFBs' feeding rates and caused highest rates of mycoses. The two new fungal isolates of *M. anisopliae* and *M. brunneum* were identified as highly virulent against CFB. Because of their potential as biological control agents, they will be further evaluated in field experiments.

REMOTE MONITORING BY MEANS OF THE INNOVATIVE TOOL ITRAP®: TWO YEARS COMPARISON TRIALS WITH STANDARD PHEROMONES TRAPS IN THE ITALIAN REGION FRIULI VENEZIA GIULIA

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The Directive 2009/128/EC establishing a framework for Community action to achieve the sustainable use of pesticides within several aims also expects that since 1 January 2014 the use of integrated pest management (IPM) became the baseline for all the farmers in the Union. In this framework, public bodies (as Phytosanitary Services) involved in agriculture as advisor function concerning pest management will play an important role: they have to provide weather data, pest monitoring, technical phytosanitary bulletins, and encouraging the use of forecasting models and decision support systems toward farmers.

In the North-Eastern Italian Region Friuli Venezia Giulia (FVG), grapevine is the most important fruit crop (19.000 ha), followed by apples (1.439 ha), kiwifruit (572 ha), olives (400 ha) and other fruit species as pears (305 ha) and peaches (276 ha).

Monitoring Lepidoptera species in orchards is a common practice concerning IPM to determine flights' beginning, population's evolution in field and to manage proper control strategies. The ERSA – Regional Phytosanitary Service of FVG has started several trials testing a new system for Lepidoptera monitoring called iTrap®: this is a software and hardware innovative combination that allows remote monitoring of traps on the web platform www.trapview.com thus making the process easier. Standard delta traps and iTrap® catches were compared in two locations in vineyards and one location in apple orchard in 2013 and 2014.

Considering vineyards' monitoring the target species were *Lobesia botrana* and *Eupoecilia ambiguella*. The iTrap® catches were substantially comparable with standard traps. Although mostly there was an increased number of catches counted in iTrap®, the results in terms of flight beginning and peak of the different generations were closely comparable.

Considering apple orchard's monitoring the target species were *Cydia pomonella* and *Cydia molesta*. Results were slightly less consistent than in vineyards. In 2013 *Cydia pomonella* catches observed in the iTrap® were delayed in the first generation and *Cydia molesta* ones were comparable in the first two months of monitoring.

As already observed in other Countries (Germany and United Kingdom) where similar comparisons have been carried out, the trials in North-Eastern Italy confirmed the comparability of catches in standard delta traps and iTrap®. This innovative system can be considered an additional useful technical tool for supporting pest monitoring and decision process in both vineyards and apple orchards.

EVALUATION OF DIFFERENT MODELS AND A DECISION SUPPORT SYSTEM (DSS) FOR CONTROLLING *DOWNY MILDEW* ON GRAPEVINE AND INCREASE THE SUSTAINABILITY OF THE PESTICIDE USE IN THE ITALIAN REGION FRIULI VENEZIA GIULIA

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The Directive 2009/128/EC establishing a framework for Community action to achieve the sustainable use of pesticides has been granted by D.Lgs. n. 150 of 14 August 2012 in Italy. Within several aims it expects that since 1 January 2014 the use of integrated pest management (IPM) became the baseline for all the farmers in the Union. In this framework, public bodies (as Phytosanitary Services) involved in agriculture as advisor function concerning pest management will play an important role: they have to provide weather data, technical phytosanitary bulletins, pest monitoring and encouraging the use of forecasting models and decision support systems (DSS) toward farmers.

In the North-Eastern Italian Region Friuli Venezia Giulia (FVG), grapevine is the most important fruit crop with about 19.000 hectares. This territory is characterized by high rainfall and *Downy mildew* is the most important disease affecting the vineyards. Sometimes it could be very aggressive causing damage and severe yield losses. The ERSA – Regional Phytosanitary Service of FVG, with OSMER ARPA (that provided weather data), has carried out 2 years trials testing different models and a DSS in several locations.

The main aim of this study was to evaluate and to take confidence with different models and a DSS forecasting infections in an area where *Downy mildew* appears with high pressure. Then to inform wine growers about the use of models and DSS as support tools for better management in defense strategies, according to the Directive 2009/128/EC and the Integrated Pest Management Regional Regulation.

The static model **VitiMeteo-Plasmopara** and the DSS **vite.net®**, widely used in the most important European vine regions, the well-known empirical **3–10 rule** with the **Goidànich table**, have been studied. The models and the DSS have different characteristics and features as leaf development, treatments section, active substances database, weather data, *etc*.

The two seasons studied (2013–2014) were characterized by rains on 60 out of 100 days between beginning of grapevine susceptibility phase and fruit set. The first infection, has been properly foreseen by the models and the DSS tested.

We consider that the DSS and models tested in our vineyards performed right prediction of infections and that can be implemented by advisers or winegrowers to support their decision in defense strategy as encouraged by the 2009/128 EC Directive.

After the good results obtained by the different systems further studies are foreseen for the next vegetative seasons. On-farm experiments will be set up in order to assess and evaluate the capacity of the different models and DSS to lead the fungicide scheduling under farm conditions.

BIODIVERSITY OF HOVERFLIES (DIPTERA: SYRPHIDAE) AND SEASONAL VARIATION IN VINEYARDS OF DOURO WINE REGION, PORTUGAL 50

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Syrphids provide important ecosystem services and have been indicated as useful ecological indicators, largely due to the diversity of species with different range of behavior and habitat. Some species are important biological control agents, particularly those from subfamily Syrphinae, whose larvae prey essentially on soft-bodied Hemiptera, although they may include also, on their diet, other insects such as Lepidoptera, Coleoptera, Neuroptera, other Diptera, Acari and Thysanoptera; on the other hand, the larva of the subfamily Eristalinae includes feeding modes as diverse as phytophagy, saprophagy, mycophagy and predation. In addition, adults of syrphids are flower visitors, where they look for food (pollen and nectar), having an important role in the pollination. In this work, developed under the project EcoVitis " Maximizing ecosystem services in Douro Demarcated Region vineyards" it was intended to study the composition of hoverfly communities in vineyards, as well as their fluctuation thought the growing season. The insects were monitored between April and December 2013 using white sticky traps that were checked weekly. On the basis of the collected sample 11 species from two subfamilies, Syrphinae and Eristalinae were identified. Syrphinae was the most abundant, being represented by nine species and totalizing 97.7% of the captures. *Sphaerophoria scripta* (Linnaeus 1758), *Eupeodes corolla* (Fabricius 1794), *Melanostoma scalare* (Fabricius 1794) and *Episyrphus balteatus* (De Geer 1776) were the most abundant species, representing almost 88% of the total captures. Two periods of activity were observed. The first period occurred during the spring, between the beginning of April and the end of June, coinciding with the period of spring floral abundance and blooming of spontaneous plants; the captures in this period represented about 72.8% of the total. The second period started in the middle of October and held until the end of sampling. Eristalinae only was captured in the autumn, between the end of October and the middle of November. The abundance of syrphids was higher at the end of May, while the richness was higher in the begging of November, when eight different species were captured. The Syrphidae family is an important functional group of arthropoda that in vineyards might play a role as a potential predator of grapevine pests, such as the grapevine mealybug, *Planococcus ficus* and the European grapevine moth, *Lobesia botrana.* Additionally, within Ecovitis project, it can give information about the impact of some practices of habitat conservation that are being implemented, playing a role as bioindicators.

WHICH IS THE ROLE OF NON-CROP HABITATS ON BIODIVERSITY OF GROUND-DWELLING SPIDERS IN VINEYARDS OF DOURO DEMARCATED REGION, PORTUGAL? 51

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Spiders are generalist predators that play a key role on the biological control of arthropod pests. Due to their ability to feed on a wide range of preys they can remain in the crop, even with low density of pest population; moreover, they can move from other nearby habitats and prevent pest outbreaks, early in the season, when specialized natural enemies are not yet available. Under the project EcoVitis "Maximizing ecosystem services in Douro Demarcated Region (DDR) vineyards" it was intended to demonstrate that biodiversity conservation, through the maintenance or/ and implementation of surrounding natural vegetation can result in benefits to winegrowers by enhancing conservation biological control of arthropod pests. The specific objective of this work was to study the composition of ground-dwelling spider communities in vineyards from DDR as well as to evaluate the influence of an adjacent area of natural (woodland) or semi-natural vegetation (abandoned almond grove) in the crop colonization by spiders through the season. With this objective, spiders were monitored in five vineyards, between April and October 2013 using pitfall traps. Monitoring was done along three transects in three different distances (5, 50 and 100 m) from the natural vegetation area, during three periods: mid-April to mid-June, mid-June to mid-August and mid-August to end of September. The collected sample allowed the identification of 19 families and 41 genera, from which 43 species were identified. The most abundant families were Zodariidae (25.8%), Gnaphosidae (21.5%), Lycosidae (10.8%), Thomisidae (8.9%) and Agelenidae (6.8%). For species, the most abundant were *Zodarion styliferum* (18.6%) followed by *Alopecosa albofasciata* (4.6%), *Tegenaria feminea* (3.9%) and *Xysticus bufo* (3.1%). Two species (*T. feminea* and *Z. styliferum)* were present in all farms, suggesting that they are well adapted to the region; conversely about 47% occurred in only in one of the farms. The relative abundance of 71.4% of the taxa was lower than 1%. While, there were no significant differences between farms in the richness and diversity of spiders, their abundance was significantly different. Although, apparently, in the early period, the abundance and diversity of spiders tended to be higher in 5 m than in both 50 and 100 m distance, these differences were not statistically significant. Likewise, while these indices were apparently higher inside the vineyard during the vegetative cycle (middle and late periods of sampling) the differences were not statistically significant. These results could be related to the fact that the soil of all vineyards was covered with natural vegetation, mowed during the spring and summer but whose residues were maintained in the soil. These could represent, himself, a habitat for ground-dwelling spiders, that does not need to move to other places.

MATING DISRUPTION AGAINST *LOBESIA BOTRANA* (DEN. & SCHIFF) USING ISONET-LTT DISPENSERS IN THE DOURO WINE REGION (PORTUGAL) 52

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The European grapevine moth, *Lobesia botrana* (Den & Schiff.) is the most important pest in the Douro Wine Region (DWR) where, typically develops three generations per year, being the third one, the most damaging to grapes. The use of mating disruption (MD), an environmentally friendly method to control this pest, is widely recommended in IPM strategies. Mating disruption have been registered in Portugal since 2000, with ISONET-L (Shin-Etsu Chemical Co. Ltd., Tokyo, Japan), loaded with 172 mg of E,Z-7,9-dodecadienyl acetate. The application of this dispenser over the years (2000–2010) allowed the identification of some major constraints to the use of MD in DWR, namely: the high biotic potential of the moth; the climate conditions, particularly the high summer temperatures; the effect of the winds on the distribution of the pheromone on the hill; the impact of slope; the fragmentation of many vineyards and the size of the treated area. Under ECOVITIS project, since 2011, two wine companies (Real Companhia Velha and Sogevinus Quintas SA.) have used a new pheromone dispenser, Isonet-LTT, developed and produced by the same company (Shin-Etsu Chemical Co. Ltd.), and applied in 180 hectares of vineyards, under the technical supervision of a winegrower organization (Associação para o Desenvolvimento da Viticultura Duriense- ADVID) and a research center (Centre for the Research and Technology of Agro-Environmental and Biological Sciences-CITAB). In the period of 2011–2013, the dispensers used were loaded with 300 mg of pheromone, and applied at the rate of 400 dispensers/ha, while in 2014 they were loaded with 400 mg of pheromone, and applied at the rate of 300 dispensers/ha, yielding in both cases 120 g of pheromone per ha. The main goal was to investigate the effectiveness of these two dispensers in the control of *L. botrana,* having in mind the specificity of each wine farm and year. The results obtained are critically discussed with the aim of improving the effectiveness of the application of this technique in DWR. In general MD was most effective in years of low pest population density, when applied in large areas, with more dispensers per hectare, and after consecutive seasons.

THE INFLUENCE OF NEEM BASED EXTRACTS ON THE MORTALITY, OVIPOSITION AND FEEDING BEHAVIOUR OF ADULT BLACK VINE WEEVIL (*OTIORHYNCHUS SULCATUS*) 53

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There is a growing need to identify and better understand plant extracts which can be used to affect an insect's lifecycle, feeding habits and overall fitness, rather than relying on a quick 'knock down effect' as an indicator of efficacy. Adult black vine weevils (*Otiorhynchus sulcatus*) were offered foliage treated with two solutions, each containing azadirachtin at concentrations ranging from 0–100 p.p.m. One solution (Aza1) was a commercial formulation, containing only azadirachtin (4.5%), while the second was directly extracted from neem kernels containing a known amount of Azadirachtin (1%), but also other phytochemicals (Azadirex). Foliage of *Euonymus europaeus* was treated with these solutions and offered to adult weevils who were commencing oviposition, at fourteen day intervals for a period of 8 weeks. The initial effect after two weeks with the Aza1 product reduced egg laying significantly across all concentrations, ranging from 70% (10 p.p.m), 90%(50 p.p.m) to 92% (100 p.p.m) compared to the untreated control. Similarly, the egg hatch rate decreased from 73.5% in the untreated controls to 34.4% at the 100 p.p.m application rate. A similar effect was observed with the azadirex solution with egg laying significantly reduced by 90% (50 p.p.m) to 100% (100 p.p.m) compared to the untreated control. Similarly, the egg hatch rate decreased from 73.5% in the untreated controls to 57.9% at the 50 p.p.m application rate. These trends were largely repeated over the next two application periods (4 weeks). After 6 weeks, all remaining weevils were offered untreated foliage to observe if there was any recovery in oviposition. Adults previously fed aza1 at 100 p.p.m did not recover and laid significantly less eggs than the untreated control (Aza1 $p = 0.007$; Azadirex $p = 0.006$). Overall there was no statistical difference in the number of vine weevil adults surviving to the end of the experiment and up to concentrations of 100 p.p.m of aza1 no statistical decrease in foliage consumption was observed. Overall there was a dose dependent decrease in the total cumulative number of viable eggs laid by adult weevils following consumption of foliage treated with both aza1 and azadirex. Similarly the pooled viability of any eggs laid decreased in a direct dose dependent manner. All data was combined and a binary logistic regression was performed to establish the statistical likelihood ('odds ratio') of egg laying under each treatment. The analysis indicated that for every 1000 eggs laid by adults fed untreated foliage, 13 eggs would be laid by adults treated with azadirex (100 p.p.m) and 34 by adults treated with aza1 (100 p.p.m). The persistent impairment of BVW reproduction following ingestion of azadirachtin treated foliage is an important observation in the development of grower friendly IPM approaches in the soft fruit and nursery stock sectors.

ENHANCING THE SOIL FOOD WEB TO HELP CONTROL SOIL DWELLING PESTS OF FIELD VEGETABLES

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With changing EU legislation and consumer pressure leading to a reduction in the use of pesticides, new sustainable solutions are urgently needed to control the effects of field vegetable pests. Evidence suggests that soils with long and complex food webs, with more trophic links and more abundant predatory fauna, can effectively suppress plant pathogenic organisms. The project aim is to test this hypothesis for the damaging Brassica pest *Delia radicum* (cabbage root fly, CabRF) at two established fully factorial field trials, in Kinsealy (Ireland) and Newcastle (UK). At both sites the soil food web will be quantified over at least a two year period and key soil parameters also determined. The abundance of entomopathogenic fungi, nematodes, predators and parasitoids will be specifically monitored and abundance and damage from CabRF will be assessed on site. First growing season data in Kinsealy indicates that agronomic practices such as soil fertility and crop protection treatments, as well as variety choice, clearly influence soil biology and impact the target pest at different life stages. Soil respiration is affected by crop protection methods, with soils sampled from organic crop protection plots (OP) respiring more than soils from the conventional crop protection (CP) soils (on log scale, CP=1.39±0.039, OP=1.46±0.035, F=13.44, p=0.035). Soil fertility treatments affect nematode community composition, as organically fertilised soil communities are less disturbed than the conventionally fertilised (maturity index OS=1.66±0.16, CS=1.27±0.15, p<0.001). This constitutes the first indication of agronomic practices having an impact on the soil food web in this study. Field monitoring data show that at the beginning of the season more eggs can be found in the organically fertilised plots (OS=8.53±0.78 eggs per 40mL soil sample, CS=5.05±0.56 eggs per 40mL soil sample, F=27.11, p<0.001), however the 2nd generation egg count seems to be more affected by the type of crop protection used than the soil fertility treatments (OP=9.01±0.72, CP=12.21±0.87, F=12.55, p<0.001), hinting at possibly different influences of practices over the growing season . Pupae count and feeding damage at the end of the 1st generation are mainly influenced by protection treatments, but crop variety choice also matters. Invertebrate activity and parasitism data are being analysed to determine possible impacts of those practices on natural enemies. Detailed laboratory experiments will consequently be designed to determine the effects of different soil food web complexity on the cabbage root fly egg laying, growth and development in soils taken from field sites. Experimental results, together with input from growers to better understand the interactions between soil and pest, could lead to enhanced control field conditions.

BIOSTIMULANTS – THE USEFUL TOOLS FOR IPM SOLUTIONS 55

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The main objective of IPM strategies is the use of various agricultural techniques to reduce pesticide input and to decrease the cost of production and to increase the yield per area unit. Lower pesticide input however advantageous for humans and environment can enhance biotic stress of plants. Moreover, combining different methods of plant protection, under some specific conditions, can lead to increased crop abiotic stress sensitivity. This is especially clear with respect to integrated weed management when intensification of non-chemical methods of weed control may impair crop and change soil conditions in the longer term.

In recent years a growing interest has been observed with natural biostimulating substances and several materials that may regulate growth and production have been placed on the market. Biostimulants are products that can modify physiological functions of plants, strengthen plant defenses against different biotic and abiotic stresses and improve nutrition efficiency. Usually they are known as 'plant conditioners' which help plants to adapt to unfavorable conditions. These plant conditioners suppress or eliminate plant growth-limiting factors affecting plant during its life. They protect plants and work differently from other plant protection products. They are also not fertilizers because their main function is not to deliver nutrients to the plant.

In the last few years the importance of preparations containing marine algae (seaweeds) for biostimulation of cultivated plants has been growing. Seaweeds constitute the most essential live organisms used as biostimulants on a wide scale commercially, and extracts from seaweeds are commonly called seaweed liquid fertilizer. They have been mostly reported to increase resistance to diseases and environmental stresses. Phytohormones contained in algae help plants adapt to stress conditions mainly by stimulation of the root system development and maintaining constant cell hydration. It has been demonstrated that algae effect greatly depends on used dose, frequency of application and species of the treated plant. Seaweeds promote root and shoot growth, nutrient uptake and photosynthesis efficiency.

The second group of more and more widely used biostimulants are humic substances including humic and fulvic acids. They are major components of humus which contains most of known trace minerals. Humic substances exhibit the action similar to extracts from seaweeds, although a bigger importance in the development of the plant root system are ascribed to them. Humic acids are considered to be compounds increasing permeability of cellular membranes in plants, and recent studies prove that these substances significantly increase the seed germination energy, the intensification of the seedling growth and the biomass development of roots and shoots. The suppressing effect of humic and fulvic acids on the development of some pathogens is also known.

For over 10 years in the Institute of Plant Protection – National Research Institute in Poznan (Poland) there are conducted glasshouse and field experiments with several groups of biostimulants, particularly seaweeds and humic substances but also mineral biostimulants (caolin clay). The aim of the experiments is evaluation of influence of these substances on growth, development and yield of some the most important crops as oilseed rape, wheat and maize depending on technique and frequency of treatments. The main object of the all studies is determination of such conditions of biostimulants application that would be the most advantageous for crops.

A NATIONAL FIELD EXPERIMENT NETWORK TO ANALYSE PESTICIDE-FREE CROPPING SYSTEMS IN ARABLE CROPS

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In 2011, the INRA/CIRAD Integrated Pest Management Network set up a national pesticide-free trial network in France, called Rés0Pest. Its purpose is to produce new references and knowledge for the design of innovative cropping systems less reliant on pesticides. Its two main objectives are:

- Designing and testing cropping systems under the constraint of using no pesticide and assessing their agronomic, environmental and socio-economic performances;
- Analysing the effects of pesticide-free cropping systems on pest populations and natural biological regulations.

Tested cropping systems were designed using Integrated Pest Management principles by combining different techniques to enhance biological regulations in order to limit damages caused by pests. Each tested cropping system is adapted to the local production situation and is designed according to the same set of:

- Constraints → èno pesticide use (except for biopesticides), cultivation of the regional major crops;
- Objectives → to maximise, under these constraints, crop production satisfying market specifications, while reducing other environmental impacts and maintaining economic profitability for farmers.

The network includes seven long-term experiments implemented since 2012 in INRA experimental units and one agricultural high school, in a wide range of production situations in France. The plot areas are at least 0.5 ha, in order to be representative of commercial fields. In addition, 50% of crops of the rotation are tested every year in the experiment. A set of protocols was written in order to standardise data collection and to allow (i) future agronomic diagnoses and performance analyses, (ii) cross-cutting analyses within the network. In these tested cropping systems, biological diversity is enhanced by diversifying crop sequence or by associating several species or cultivars in the same field. Many other technics with partial effects on pest regulation are combined in the tested cropping systems.
The pesticide free cropping systems tested in the Rés0Pest network are prospective, ambitious in terms of pesticide reduction and are implemented in a large range of production situations. Thus, Rés0Pest represents a unique experimental tool in France for research programs related to agroecology. The system approach used in long-term field experiments is also original and permits to analyse long-term effects of cropping systems on the environment. Currently, some specific protocols are being written to characterise pest injury levels and biological regulations. New collaborations have to be initiated and developed in order to fully take advantage of the network.

Acknowledgements
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INJURY PROFILE SIMULATOR (IPSIM), A MODELLING PLATFORM TO DESIGN QUALITATIVE MODELS PREDICTING INJURY PROFILES AS A FUNCTION OF CROPPING PRACTICES AND PRODUCTION SITUATIONS 57

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In order to reduce the reliance of agriculture on pesticides, there is a need for tools to help design agroecological management strategies of pests. In particular, the "vertical integration" (combination of several control methods) and the "horizontal integration" (simultaneous management of several pests) embedded in the Integrated Pest Management concept, require methodological developments to be successfully implemented. We propose an innovative modelling framework in order to help design qualitative models to represent the impact of cropping practices, soil, climate and field environment on injury profiles caused by multiple pests (plant pathogens, weeds and animal pests). This communication presents the basic principles of the approach and an application to wheat, the main arable crop in Europe in terms of cultivated area.

IPSIM is a simple generic hierarchical qualitative modeling platform based on the DEXi software. The main assumption of IPSIM is that each injury profile that can be observed in a given field only depends on the associated cropping system and part of the production situation (described in terms of soil, climate and field environment). DEXi is thus used to easily design hierarchical deterministic Bayesian networks (i.e. with probabilities only equal to 0 or 1) based on nominal and ordinal attributes describing agroecosystems. The structure of the model and the way attributes are aggregated together are determined using expert knowledge, along with technical and scientific literature. In addition, converters are needed upstream in order to convert quantitative or nominal input variables into ordinal variables.

In order to provide a proof of concept, the method was first applied to a single disease: eyespot on wheat. IPSIM-WHEAT-EYESPOT, a sub-model of IPSIM-WHEAT, was designed and its predictive quality was assessed on a large dataset (525 site-years over 9 years for 19 French regions). IPSIM-WHEAT-EYESPOT proved to fairly represent the effects of cropping practices as well as the regional and annual variability of the disease (Efficiency = 0.51, Root Mean Square Error of Prediction = 24%; bias = 5.0%). It is remarkable that these performances were obtained without any calibration. This model is now available to help design cropping systems with low risk of eyespot on wheat in a wide range of production situations, and can help perform diagnoses of commercial wheat fields.

The platform IPSIM appears to be an innovative tool to design qualitative models predicting injury profiles to help design agroecosystems less reliant on pesticides. The lack of precision of the approach (i.e. use of qualitative attributes) is actually one of its strengths, as it permits to combine various sources of knowledge: various datasets (field experiments and diagnoses of commercial fields, expert knowledge, and pre-existing models) and certainly gain in robustness. We believe that the platform IPSIM is a step towards more holistic modeling approaches addressing higher level of complexity for the sustainable management of agroecosystems.

Acknowledgements

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SEARCH FOR THE MARKERS ALLOWING FOR DIFFERENTIATION BETWEEN AGRICULTURALLY IMPORTANT THRIPS SPECIES 58

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Thrips are common plant pests of crops that feed by puncturing the epidermal layer of host tissue and by sucking out the cell contents, causing in this way large damages in the plant quantity and quality. The most harmful species are *Thrips tabaci* Lindeman, *Frankliniella occidentalis* Pergande, and *T. palmi* Karny. The last one is under quarantine regulations in European Union (EPPO/CABI 1997). For non-specialists, larval stages of these agriculturally important pests are morphologically indistinguishable, *e.g.* in the case of *T. palmi* and *F. occidentalis* as well as other frequently occurring thrips.

Taxonomic identification of thrips species is an important element in the integrated and biological plant protection. To ensure proper diagnostics, molecular biology techniques are employed, on the basis of which several protocols for thrips detection have been developed. However, the emergence of new sequences in the GenBank database as well as recent reports revealed the existence of variants of the same genetic marker within one species. Thus, it seems that there is a risk that some of protocols might not amplify all of these variants or might give cross-reactions with non-target species.

In this study, we have focused on the characterization of genetic markers typically used for the differentiation of the most harmful thrips. We analyzed their usefulness in their diagnostics by comparison of DNA sequences obtained in this study for several *Thrips* and *Frankliniella* species as well as data available in GenBank. The analyzes were done on *mtCOI/mtCOII* genes, rDNA fragments, and sequence-characterized amplified region (SCAR) marker obtained in RAPD analysis. In this way we were able to indicate sequences which can be used for genetic differentiation of these harmful pests.

A SIMPLE GRAPEVINE GROWTH MODEL: TOWARDS GRAPE-PEST, A X-PEST MODEL OF DAMAGE CAUSED BY MULTIPLE PESTS ON GRAPEVINE

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In most growing regions, vineyards are submitted to numerous biotic stress. Environmental and social drivers, along with regulations urge growers to lower the use of pesticides they apply to limit yield loss caused by animal pests and diseases. There is a need for a modelling tool to help understand and quantify yiel loss resulting from injury profiles. Available models usually describe one pest or pathogen dynamics, rarely the resulting loss. As a joint action between WP1 and WP6, we developed a simple grapevine model that will be the cornerstone of a model predicting yield loss caused by multiple pests on grapevine. Eventually, this tool will contribute to the design of Integrated Pest Management strategies in vineyard.

The objective of this work was to develop a simple grapine growth model that will be implemented within the XPEST platform in order to represent damages caused by multiple pests on grapevine.

The work consisted in adapting the Monteith's equation to grapevine using published data and original experimental datasets. The basic principal of the model is that intercepted solar radiation is transformed into assimilates that are allocated to three organs: leaves, stems and clusters. The model developed is deterministic. It works with a daily time step for 1 m^2 crop. Simulations start at budburst and ends at maturity. Phenology is fully described using a continuous development stage scale as a function of thermal time (10 °C basis). Input variables are: mean daily temperature, incoming solar radiation and Radiation Use Efficiency dynamics. State variables are: Leaf Area Index and organ biomasses. The main output variable is yield (i.e. cluster biomass at harvest).

A first version of this model was developed in R. Its parameters were estimated using a threee year dataset, collected in the Languedoc-Roussilon region (south of France). The general shape of the simulated LAI and fruit biomass dynamics were similar to observations. However, the goodness-of-fit statistics pointed out the need to take into account so far neglected processes to better predict LAI.

This work is a first attempt to model grapevine ecophysiology in a simple way. In this first step, several assumptions were made that will need further attention. First, the stocking process was not taken into account. Second, it was hypothetised that no water stress occured. This assumption is certainly not realistic for many production situations and will require the development of an additional sub-model. The model developped will be implement in the X-PEST platform which will allow to couple this growth model to a set of damage functions of the main pests on grapevine in Europe: downy and powdery mildews; berry moth; and grey mould.

IDENTIFICATION OF WHEAT PROTEASE INHIBITORS ACTIVATED IN RESPONSE TO CEREAL LEAF BEETLE FEEDING 60

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Cereal leaf beetle (CLB, *Oulema melanopus*, Linnaeus) is an important economic pest of cereals, especially of wheat and barley. Both, beetles and larvae damage the leaves of cereals, which has a significant impact on the quality and quantity of crop yield. To limit damages of pests in the first place agronomic and biological methods should be applied, according to the principles of integrated pest management. Since many insect species of agricultural importance has adapted to insecticides, recent studies are focused on the investigation of insect digestion and a potential possibility of application of natural enzyme inhibitors for pest control. Plants are known to produce their own protease inhibitors as a defense mechanism against feeding damage caused by insects. Protease inhibitors can restrain proteolytic enzymes produced by the digestive system of insects. Therefore, protease inhibitors might constitute an important element in protection of plants against herbivorous insect in the future.

In this study, we have undertaken first to identify the proteolytic enzymes of digestive system of CLB using set of in gel activity assays and spectrophotomeric measurements. Then, we have analyzed the expression levels of plant genes encoding for protease inhibitors in response to feeding of CLB larvae. The gene expression was assessed by using real-time PCR technique. We found out significant differences in expression of plant protease inhibitors treated by CLB. The plant response differed depending on the kind of treatment, time of analysis after leaf damage, and on wheat variety analyzed.

ECOPHYTOPIC: THE FRENCH IPM WEBSITE – 2 YEARS OF EXPERIENCE 61

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Two years ago the Ecophytopic portal (ecophytopic.fr) officially entered the panorama of the IPM in France.

A rich content

This portal consists of seven platforms dedicated to six agricultural sectors with one more global platform with definition and on-going information. The target of this portal is the different stakeholders involved in IPM and mainly advisers, trainers and farmers. On short-term side, EcophytoPIC relies on the principles of IPM, developing preventive techniques and control methods (biocontrol, physical methods, optimization of chemical control) and addressing the whole area of monitoring, diagnosis and decision. Concerning the practical case, the Dephy network set up under the Ecophyto, provides a lot of information at the farmer and the experimental levels. This network will become an important source of information in EcophytoPIC with technical data, analyzes and briefs. In long term side, EcophytoPIC is looking for new techniques and field testing that should help to contribute to the objectives of reducing the use of pesticides.

EcophytoPIC team identified all past or current national and European programs and provides access to the understanding of projects but also all the results and deliverables of these projects it aims to. These are available in two special sections (Innovation, Research) but can also feed the sections on technical methods of control and surveillance. Again, the Dephy network, through its program of experimentation, but all CASDAR projects (founding by the French Ministry of Agriculture) are described with an explanatory note and all available deliverables.

A dynamic in Ecophyto plan

In December 2012, the first four platforms (all crops, field crops, vegetable crops, fruits) were open to the public. End of 2013, two new platforms (viticulture, horticulture) pursued the construction of the portal.

Finally 2014 is an important year after the opening of the last platform (tropical crops), by focusing on the development of new tools. Among them, a dedicated trainers training platform was launched in October. This platform is an introduction to IPM and allows trainers to have a more holistic vision as possible on the subject but also to get access to portal resources. Additional functionality for non-agricultural sectors was developed with links to the two portals devoted to them. Next, the team works on the development of an interactive tool to raise awareness in the design of efficient systems less dependents of plant protection products. This tool will complement guides with a more direct and playful approach but also due to links to resources in the portal. This tool will be online in the first quarter 2015. EcophytPIC is also french news in the field of IPM:

– Calendar: Dates of events and conferences and links to the papers presented at these events

– Press review: monthly inventory of articles from journals

– Focus: folders on a specific topic by connecting the resources of the portal; currently seven cases up this topic; the frequency of publication of these records is 3 to 4 per year

– Testimonies: Video making an inventory of the use of alternative methods; testimony is the opportunity to link different sections

– Europe: setting link to databases, guidelines and guides IPM products in different European countries. At this moment, thirteen countries are represented.

So EcophytoPIC is now a documentary database with more than 1,400 articles and 6,000 references, but also more than 130 news. You may participate in, by sending your document at ecophytopic@acta.asso.fr

ISIP – THE ADVISORY PORTAL FOR PLANT PRODUCTION IN GERMANY 62

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ISIP, the Information System for Integrated Plant production, is a Germany-wide online decision support system. It has been initiated in 2001 by the German federal extension services as a common advisory portal, thus achieving synergies by pooling existing information. Despite the centralised character of the system, the regional identity of the co-operating services was to be preserved by a distributed administration and data input.

Since information transfer is the primary task of extension services, the system is intended to make this work more efficient by using modern IT. By combining general with specific data, recommendations can be refined from regional to individual. The information is primarily distributed via HTML pages; the usage thus requires only a browser on a desktop computer (www.isip.de) or a mobile device (m.isip.de).

Three types of information can be distinguished in ISIP, differing in scale. The most general information is given in an encyclopaedia, where background information and standard recommendation for more than 20 crops and 200 pest and diseases are available. More specific information is provided in regional news. The members of the ISIP association can maintain own pages in the system, where they can distribute topics ranging from contact data to legislative news. Decision support modules (DSM) deliver the most specific results. They comprise results from a simulation model (mainly delivered by ZEPP – see separate presentation) and/or monitored field observations as well as a comment of the regional extension officer. This concept of the 'threefold decision support' gives a comprehensive overview for a defined pest or disease.

Decision support modules provide a very efficient way of knowledge transfer. Scientific results can be used in practice when presented in a straightforward manner. DSM are shown in ISIP as maps, tables and graphs. Maps present data in a geographical information system (GIS) for a regional overview. Tables and graphs give a more detailed view in a specific area. A limited set of colours and icons provide for a consistent interface for the user. To release the user from having to check his individual results consistently, an automatic warning service can be set up. When a module-specific threshold is exceeded, an SMS or e-mail is generated by the system and sent to the user.

The advantages of the ISIP system differ between the two target groups. On the one hand, the farmer gains most from the on-line calculation of prognosis models which deliver site-specific recommendations. Furthermore, the automatic warning service reduces online as well as response times especially for time-critical decisions. On the other hand, extension officers benefit from the mobile input of monitored field data and advisory comments. This eliminates further processing and ensures a fast and efficient information transfer.

ZEPP – DECISION SUPPORT SYSTEMS FOR PLANT PROTECTION IN GERMANY

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The mission of the Central Institute for Decision Support Systems in Crop Protection (German acronym ZEPP, founded 1997) is to collect and examine existing predictive and simulation models for important agricultural and horticultural pests and diseases and to develop these models for practical use. Moreover, the development of new predictive models for further pests and diseases is tackled in numerous projects.
A universally applicable time-reduced procedure enables ZEPP taking up scientific model approaches, to adapt and validate them regionally in order to introduce them to practical use. The realisation is carried out in close cooperation with research institutions in Germany, e.g. the Julius Kühn Institute, universities and others. In addition, a number of cooperation contacts exist to European partners by participation in EU financed projects. More than 40 met-based predictive models for pests and diseases in arable crops (e.g. cereals, oilseed rape, potato and sugar beet), horticulture (e.g. cabbage and carrots), fruit-production (e.g. apple, peach and cherries) and minor crops (e.g. lupine and tobacco) have been successfully developed and introduced to practical use by officers of the governmental crop protection services as well as farmers. The occurrence of pests and diseases and periods of high-intensity attacks can be calculated with high accuracy. Thus it is possible to optimise the timing of control measures in combination with a high effectiveness and thus contributing to an environment-friendly agriculture. The predictions are suitable for both integrated and organic farming. Plant protection products are being saved particularly in fungal control of potatoes and cereals as well as for aphid control of cereal crops. Further models are in the process of introduction to practical use.
The calculation of pest attack and disease epidemiology is based on more than 570 met stations using the latest information technologies and media. Furthermore, to increase the accuracy of the models, the use of Geographic Information Systems (GIS) was introduced on the simulation process. The influence of elevation, slope and aspect on temperature and relative humidity were evaluated with GIS methods to interpolate these parameters, whereas precipitation data are obtained from radar measurements. These spatially high resolved meteorological data are then used as input for the simulation models. The output of these models is in turn presented as so-called “risk maps” in which areas of maximum risk of a disease are displayed. It is expected that the introduction of GIS methods to increase spatial accuracy increases system adoption by farmers and advisors.
An exemplary demonstration of such Decision Support Systems can be accessed on www.isip.de

EFFECTS ON NATURAL DERIVED PRODUCTS ON THE TOMATO RUSSET MITE *ACULOPS LYCOPERSICI*

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The tomato russet mite *Aculops lycopersici* is an important pest of commercially grown tomato *Lycopersicon esculentum*, but its host range includes other worldwide important vegetable and ornamental crops (e.g., eggplant, potato). Effective biological control strategies against this pest have not been developed and its control is based on acaricide use. Among potential alternatives to conventional pesticides, the use of natural enemies is limited by tomato glandular trichomes that hamper the activity and the establishment of predators on plants. Other alternatives are represented by products based on entomopathogens and plant-derived substances. We evaluated the effects of three products based on entomophathogenic fungi (*Beauveria bassiana*, *Paecilomyces fumosoroseus* and *Lecanicillium muscarium*) and two products based on plant-derived substances (pyrethrins and azadirachtin) on *A. lycopersici* in the laboratory. The experiment was performed by exposing tomato russet mite adults to dry residues of the tested products. A water treated control was also included for comparison. The effects of products were evaluated in terms of survival and escaping rate after 72 and 168 hours from application. The survival of *A. lycopersici* was reduced by pyrethrins and azadirachtin but especially by *B. bassiana*. Escaping rate of russet mites was also influenced by treatments. Escaping rate was higher where azadirachtin, pyrethrins, *L. muscarium* and *P. fumosoroseus* were applied as compared to the control and *B. bassiana* treatments. Results are discussed in the framework of Integrated Pest Management on tomato.

FIRST APPROACH PREDICTING ASCOSPORIC INFECTIONS OF GRAPEVINE POWDERY MILDEW IN THE DOURO WINE REGION USING A MECHANISTIC MODEL

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The grapevine powdery mildew caused by *Erysiphe necator*, is the main disease of the Douro Wine Region (DWR), having in this region an endemic behaviour. This region have around 45000 ha of vineyards, divided in three sub-regions clearly distinct from the climatic point of view. The fungus overwinters mainly in the form of clamosthecia since the flag shoots (caused by the parasitized buds) are rarely observed. The beginning of his capture always occurs before budbreak (BBCH stage 05) and usually end by the ripening phase (BBCH stage 69–71). Disease management strategy is usually based on fungicide applications, according the phenology, performed from pre-flowering (stage BBCH 53) to bunch closure (BBCH stage 79). The existence of weather stations in the region allowed to collect the data necessary as input for running the model for ascosporic infections developed by the University of Piacenza (Italy) and provided by Horta srl (www.horta-srl.com). This model simulates the ascospores maturation curve, the infection periods, the progress of latency and the possible symptoms onset. In 2014 a collaboration was started in order to test the applicability of this model in DWR with the aim of reducing the number of treatments in the control of the disease throughout the vegetative cycle, minimizing their impact on the environment and maximizing their efficacy and, finally, reducing input costs for growers.

THE NEGATIVE PROGNOSIS PLANT PROTECTION MODEL AND WEATHER DATA QUALITY

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Abstract: The EU member countries were obliged to enforce integrated plant protection (IPP) as of 1 Jan. 2014. General guidelines for applying plant protection products in accordance with the IPP principles are determined by the EC 1107/2009 regulation. In its infancy (the '90s of the 20th century) the IPP was implemented mainly on the basis of the knowledge of human experts. The rational selection of a plant protection product has to be preceded by a thorough analysis of cultivation status. In the analysis variety resistance, developmental phase of the host and the pest, abundance of the infection source, weather conditions, the product properties, rotation of products with different modes of action, occurrence of resistant pest forms, as well as many other factors should be taken into consideration. The need to take a number of factors into account makes the IPP difficult to apply in the field, especially so in the case of combating simultaneously multiple diseases. This is one of the reasons that at present more and more universally decision support systems (DSS) are being used in farm practice to facilitate decision making. Three DSS types can be enumerated for determining the need for protection treatments: symptom-based, meteorological and combined. In symptom-based systems the need for treatments is determined on the basis of assessment of increasing disease symptoms or damage; meteorological systems on the other hand do not require field scouting as they use mathematical models to determine the pest developmental stage depending on the existing weather conditions. Combined systems are a combination of the two.
In meteorological and combined systems weather data quality plays the fundamental role in the correctness of generated recommendations. The knowledge about potential effects of inaccurate weather data and data verification procedures is of utmost importance when using meteorological plant protection models in practice.
The Negative Prognosis plant protection model is a meteorological model that has been used in the farming practice for a long time now for controlling potato late blight, caused by *Phytophthora infestans*. The Institute of Soil Science and Plant Cultivation – State Research Institute (IUNG – PIB) makes it available within the „Internet decision support system in the integrated plant protection". The Negative Prognosis input is comprised of hourly weather data coming from the IUNG – PIB's agrometeorological station net. Three weather elements are taken into account: air temperature, relative humidity and precipitation sum. The model generates recommendations on the first protective treatment in the vegetative season based on the estimated infection risk. Since the weather data constitute the only source of information for the recommendations, there exists a direct dependence between data quality and the recommendations quality. The Negative Prognosis model is particularly sensitive to the data quality, especially in periods of intensified disease development brought on after several days' heavy precipitation and moderate temperature.
The objective of the work was to determine the Negative Prognosis model sensitivity – to show the impact of data on the infection risk calculation and on the quality of generated recommendations (accuracy of establishing the date of the first protective treatment). Simulations were conducted on the model using the data generated specially for the simulation experiment. Based on the results achieved, a sensitivity characteristic was developed for the model enabling an insight into the model requirements in terms of weather data quality. The quality of the Negative Prognosis model recommendations for the data coming directly from measurements and the corrected data was also assessed by comparing calculated results. In this way the quality of weather data from the IUNG – PIB's network was assessed in relation to the requirements of the model. The conducted investigations made it possible to establish that a critical weather element for the quality of recommendations was the air relative humidity. Small changes of air humidity (1–5%) caused relatively pronounced changes of the date of the first treatment (1–13 days), depending on the assumed potato emergence date. It also showed that the direct measurements could be of poor quality and may lead to wrong recommendations. An implementation of a verification and data correction system is therefore essential.

DIMETHYL DISULFIDE (DMDS) IN THE SUSTAINABLE CONTROL OF THE CYST NEMATODE *HETERODERA CAROTAE* AND THE ROOT-KNOT NEMATODE *MELOIDOGYNE JAVANICA* ON CARROT IN SOUTHERN ITALY

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Two field trials were carried out in Apulia region (Southern Italy) in the years 2012 and 2013 to verify the efficacy of dimethyl disulfide (DMDS) in shank application against the carrot cyst nematode *Heterodera carotae* and the root-knot nematode *Meloidogyne javanica*, respectively. DMDS is an innovative soil fumigant for a modern and sustainable soil management. In both trials soil was subdivided in 4 x 50 m plots for shank application of the fumigant. Each plot was subdivided in 5 sub-plots to provide replications for each treatment. DMDS was applied at rates of 180, 280 and 370 L/ha and then covering the soil with VIF plastic film. Untreated soils were used as controls. As chemical controls were considered 1,3 dichloropropene (140 L/ha) in the year 2012 and oxamyl (50 Kg/ha) in the year 2013. In the second trial regarding the control of *M. javanica*, for the lowest dose of DMDS (180 L/ha) the soil was covered after shank fumigation not only with VIF film but also with TIF film. Films were removed in both trials 15 days later their applications and the soil aired for further 15 days. After soil aeration carrot (cv Bolero in 2012 and cv Exelso in 2013) was sown. In the first year before sowing, soil samples were collected in each plot to extract cysts by the Fenwick can. Cysts, collected from treated and untreated soils, were subjected to a hatching test to verify vitality of their eggs. Hatch percentage in untreated control was significantly higher (35.2%) than those observed in all other treatments (< 0.36%) that were not significantly different each other (P = 0.01). At the end of the experiment no significant differences were observed in the number of cysts among the different treatment included the untreated control (P = 0.01). The higher and significant marketable carrot yield was recorded in plots treated with DMDS at 370L/ha (575 q/ha) (P = 0.01). Other treatments were significantly lower than DMDS at 370 L/ha. In the untreated control no marketable yield was harvested. In the second trial on *M. javanica*, at the end of the trial, soil samples were collected to extract eggs and juveniles by the Coolen's method. The lowest soil nematode population was observed in soils of plots treated with DMDS at rate of 370 L/ha and it was significant lower than those observed in oxamyl and untreated plots (P = 0.01). However no statistical differences were observed among the different rates of DMDS and between the two plastic films VIF and TIF (P = 0.01). The highest carrot marketable yield was observed in all three applied doses of DMDS covered with VIF (P = 0.01). In untreated control marketable yield was significantly lower than those observed in all other treatments (P = 0.01). Results providing evidence that DMDS represents a sustainable technical solution for controlling root-knot and cyst carrot nematodes. Further trials to control nematodes, combining DMDS with not chemical solutions, are ongoing for a sustainable soil management.

IPM IN US SCHOOLS: REDUCING RISKS FROM PESTS AND PESTICIDES AND INCREASING AWARENESS AND APPRECIATION FOR IPM AMONG CONSUMERS AND TAXPAYERS

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More than 40 reports over the past twenty years have documented unmanaged pest problems and high risk pesticide use practices in US schools. In 2006, a broad-based coordinated national effort was initiated with ongoing support from US EPA USDA to achieve verifiable IPM at an advanced level along the IPM continuum in all US schools by 2015. The work has included traditional models including demonstrations and publications; novel peer-to-peer regional learning communities composed of school district representatives, agency representatives, contracted service providers and others; making the connection between environmental justice, cockroaches, and childhood asthma and obesity; addressing new pest challenges including bed bugs; and social networking to a new contact database of facility managers at school districts nationwide. Our 2012 survey indicates we now have IPM in school districts in more states than ever before, with about 20% of school districts nationally implementing key elements of IPM. Momentum continues to build, including a recent commitment of an additional $1.5 million USD annually from US EPA and designated school IPM lead staff in each EPA region. Performance metrics include reductions in both pest complaints and pesticide applications, numbers of school districts and children impacted, leveraged funding, and school districts with IPM policies, plans, coordinators and other programmatic elements. Achieving IPM in US schools has implications for agriculture including increasing policy maker, consumer and taxpayer awareness and support for IPM and providing a model for coordinated efforts to achieve IPM objectives in other arenas.

IPMPRIME.COM: FARMER-FRIENDLY ON-LINE TOOL FOR PESTICIDE RISK ASSESSMENT AND MITIGATION

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Pesticides are critical tools for food and fiber production. Pesticide risks are real but can be carefully managed to minimize adverse impacts. Much progress has been made to reduce pesticide risks, including many new reduced-risk products and proven mitigation strategies, and ready access to this information will help reduce adverse impacts and improve environmental stewardship. Ipmprime.com is an innovative on-line tool for growers, their advisors and others to assess pesticide products and uses for impacts on soil, water and air quality, avian and aquatic life, beneficial organisms, and worker and consumer health and safety. The tool applies the best available science to permit producers, advisors, IPM and sustainability managers and others to compare different pest management scenarios for any commodity and select options with the fewest potential environmental and health hazards, and to identify mitigation options for products/uses selected. By providing ready on-line access with a farmer-friendly interface and addressing a comprehensive set of resource concerns, ipmprime.com offers several advantages over alternative systems including the Environmental Impact Quotient and the US Department of Agriculture Natural Resources Conservation Service Windows Pesticide Screening Tool. Ipmprime.com is currently in use in major multinational food company initiatives in the US.

WHAT IS SPECIAL ABOUT THE REGISTRATION OF BIOLOGICAL PLANT PROTECTION PRODUCTS 70

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Biological plant protection products containing microorganisms or plant extracts ("botanicals") as active ingredients are no longer limited to organic agriculture, they are also gaining more and more importance in integrated production schemes. This is due to the fact that most of them have little effect (if any at all) on human health, non-target organisms, and the environment, resulting in few or no use restrictions like pre-harvest intervals.

However, registration of Biocontrol Products is still facing particular problems. This is partly due to the fact that some data requirements which can be easily covered for synthetic chemicals cannot be fulfilled for biocontrol products and their actives for technical reasons. On the other hand, the major advantage of many biocontrol products is that their active ingredients are scientifically well known and humans are familiar with them either through direct use or environmental exposure for a long time. Information on the precise taxonomy is the key to determine which experimental data are needed. Publicly available information together with specific studies can be in many cases used to cover data requirements for microorganisms and plant extracts. Risk assessment for these products can be conducted based on these data and safe uses can be demonstrated with an effort that is proportionate to the real risk from such products.

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.

IMPLEMENTING IPM IN STRAWBERRY PRODUCTION IN FINLAND BY UTILIZING DEMONSTRATION FARMS AND EXPANSIVE LEARNING

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The IPM implementation in strawberry crops was supported in demonstration farms to encourage the use of selective pesticides, biocontrol and decision making based on pest monitoring. Another objective was to study the learning process of growers who implemented new IPM elements to better understand the between-farms variability in implementation success. The IPM concept among ~ 200 berry producers was first defined from the discourse data of group interviews. The majority of growers conceived IPM as increased efficiency of pesticide use, i.e. as first stage IPM. In the group interviews, strawberry producers named documentation and learning from it, and the use of action thresholds for pest control, as the most challenging IPM elements although many were already using them. Therefore, the project was later focused on these elements. In four demonstration farms, growers were guided to the use of monitoring methods and to documenting monitoring results in a web-based prototype of IPM portal. Each farm had a conventionally managed plot and an IPM-plot where management actions were guided by pest monitoring results. The success of pest management in both plots was verified by flower stalk analysis to measure the quality and quantity of the strawberry yield. After the first summer, the farmers reflected on their pest management experiences through semi-structured thematic interviews. The discourse data was analyzed for expansive learning actions using activity theory as the theoretical framework, and root conflict analysis was applied to the most interesting case for determining all pest management challenges and related issues in the farm. While reflecting, the growers modeled their own behavior, first at conceptual level then by adjusting their concrete pest management actions for the next summer. There were differences in how quickly the farmers adopted offered IPM elements, whether their learning was restricted to the offered elements or expanded also to other IPM elements and crops, and in the degree of adopting the use of the portal as a means of documentation. In all farms, pest management became more proactive. The level of pest damages was similar in both types of plots, as was the number of chemical treatments, but in IPM plots only selective pesticides with lesser ecological effects were used. In the second summer, the decision making concerning the need and timing of pesticide treatments in the IPM plots "spread" also to the conventional plots. Only one farm of the four adopted the use of the portal as a means of documentation. The results on expansive learning can be utilized for developing tools for purposes of consulting farms on their development issues, and for designing specific means of supporting IPM implementation according to the farms' specific challenges. The reflection data was found useful also for purposes of user studies when testing prototypes of IT-based tools for documentation and pest management decision-making.

DEVELOPMENT OF IPM-TOOLS FOR THE CONTROL OF CEREAL LEAF BEETLE AND APHIDS IN GRAINS

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That insects reduce yield of cereals has been proved before by a large number of researchers all over the world. The cereal leaf beetles *Oulema melanopus, Oulema gallaecianna* and *Lema Cyanella* are common plague insects in small grain cereals in the northern half round. Knowledge of optimal timing for chemical pesticide-application is absent in Europe, as well as selective pesticides approved in Flanders for the control of CLB (Cereal Leaf Beetle). Controlling grain aphids (*Metopolophium dirhodium, Rhopalsiphum padi* and *Sitobion avenae*) can interfere with the chemical control of the CLB. For the control of these leaf beetles, farmers often use broad-spectrum pesticides (pyrethrines such as lambda-cyhalothrin) in tank-mixes with another application (fungicides/nitrogen). As the – arbitrary- application is often done with wrong timing, they kill all present insects in the crop, including natural enemies. This can cause an even faster regrowth of the aphid/CLB populations, and therefore the need for a second application. With the introduction of IPM (Integrated Pest Management) by the European Parliament, January 2014, farmers are obligated to use a more integrated way to control the pests in their crops. One way to accomplish this is using selective pesticides to keep the natural enemies alive and let these "*Farmers' Friends*" help controlling the plague. In a 4 year-research-program, the aim of this study is to develop a model that predicts optimal timing of application, as well as give an advice to the farmer what selective pesticide to use. This model would be based on data from numerous fields that lay all over Flanders, Belgium. These fields are chosen based on variation in region, rotation, border management, e.g. . During growth season, parameters as population growth of the CLB, grain aphids and natural enemies of both plagues as well as the controlling effect of the natural enemies will be measured. How these parameters interact with other variables such as weather data and other field specific characteristics will be implemented into the model as well. Lastly the correlation between population density and yield will be tested. This provides the ability to set specific economic thresholds.

THE ANALYSIS OF RISK AND EFFECTIVENESS OF APPLICATION OF *SCLEROTINIA SCLEROTIORUM* (LIBERT) DE BARY IN BIOLOGICAL CONTROL OF CREEPING THISTLE IN MEADOW AGROCENOSES

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The infestation of meadows and pastures with weeds decreases the value of grass and hay. Creeping thistle (*Cirsium arvense* (L. Scoop.) is one of major unwanted plants in meadow agrocenoses. Due to the fact that the weed is capable of vegetative reproduction, it rapidly colonises stations and simultaneously, it is difficult to control. The specific character of meadows and considerable difficulties in controlling the weed encourage the application of fungal pathogens to limit the population of *C. arvense.*

There were two aims of the study. The first aim was to select the most pathogenic *S. sclerotiorum* isolate against *C. arvense* from a few isolates deriving from different species of plants. Apart from that, in view of the wide feeding range of the fungus, the study analysed how dangerous the isolates applied for weed control would be to commonly grown vegetables and ornamental plants.

The *S. sclerotiorum* isolates selected for the study came from creeping thistle, ranunculus, rapeseed, forsythia and vegetables (courgette, beans and parsley). There were greenhouse and field experiments assessing the harmfulness of selected *S. sclerotiorum* isolates to commonly grown vegetables (beetroot, cabbage, field tomato, green beans) and tobacco. The other group of assessed plants consisted of ornamental plants (chard, gillyflower, ornamental kale, cherry tomato). Ten-day cultures of each *S. sclerotiorum* isolate under investigation were used as inoculums. They were cultured in Petri plates on a PDA medium (Sigma).

Experimental infections proved that the pathogenicity of the *S. sclerotiorum* isolates under investigation was diversified both with regard to *C. arvense* and to the other crops to which the fungus was potentially dangerous. Among the isolates under study 5C S. *Sclerotiorum* isolate proved to be the most useful. It was isolated from creeping thistles growing on natural meadows. The 5C S. *Sclerotiorum* isolate was classified into the group of isolates with medium pathogenicity against *C. arvense* and simultaneously it was characterised by low pathogenicity against crops. On the other hand, the isolate derived from rapeseed was particularly harmful not only to creeping thistle but also to common crops. Inoculations with the 5C isolate conducted in a meadow agrocenosis caused the death of 50% of the plants during the first year. The experiment proved that the isolate was useful for the limitation of the weed population.

THE EFFECT OF SELECTED AGRICULTURAL PRACTICES ON THE INCIDENCE OF DISEASES AND WEED INFESTATION IN WINTER OILSEED RAPE

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Recently the area of agricultural crops based on no-tillage cultivation systems has increased significantly in Poland. The simplified tillage system, used under good soil conditions with proper agricultural technologies allows to maintain a good stable level of crop yields. Except for oilseed rape culture , which requires properly cultivated soils.

The aim of the long-term experiment set up in 2011 was to compare some selected agricultural factors (system of cultivation, crop rotation with variable level of protection) on the incidence of fungal diseases and weed infestation in winter oilseed rape. The first tested factor was a tillage system: I – reduced tillage; II – ploughing. The second tested factor was the level of protection: b_1 – standard (current practice); b_2 – integrated (low pesticide input, including non-chemical methods). For the standard practice (b_1) winter oilseed rape was sown in rows at a row-spacing of 24 cm, with chemical weed control and winter wheat as a stable forecrop. In the integrated system (b_2) band-row sowing was used (band sowing 33 cm with inter-row 50 cm wide). Mechanical weeding of inter-row was made by hoe and the herbicides were applied only for band spraying of oilseed rape rows; narrow-leaved lupine was used as a forecrop.

In both tillage systems the same protection measures against pests (TFI value) were used. For the second tested factor the level of protection varied and the total value of TFI (sum herbicide and fungicide) was as follows: b_1 = 1,97 and b_2 = 1,0. With broad-leaved weed the following species were dominant: *Centaurea cyanus*, *Geranium pusillum*, *Viola arvensis, Matricaria inodora*, *Anchusa arvensis* and grass weed species: *Elymus repens* and *spica-venti Apera*. In the simplified tillage system weed infestation was significantly higher as compared to the ploughing.

The results of the sampled oilseed rape revealed the symptoms of infection with grey mould (*Botryotinia fuckeliana*), stem canker (*Leptosphaeria* spp.), stem rot (*Sclerotinia sclerotiorum*) and black spot (*Alternaria* spp.). The incidence of rape diseases mostly depended on the weather conditions in the particular seasons. During the first no stem rot infection was observed. The highest level of stem rot incidence in oilseed rape was recorded in the second year. In the same year a significant percent of oilseed rape plants were infected by stem canker as well as the oislseed rape siliques showed the symptoms of gray mould and black spot. Occasionally, the occurrence of funfal diseases depended on the crop rotation and on the cultivation system. In the reduced tillage system there was a greater percentage of infected plants, especially by the pathogen causing stem rot.

The results showed that despite the reduced use of chemicals in the integrated system the decrease of weed infestation and infection by fungal diseases was recorded, as well as higher yields of oilseed rape. The obtained differences between the protection practices were more evident in the reduced tillage. In the ploughing cultivation the yield od winter oilseed rape was significantly higher as compared to the reduced tillage, regardless of the level of protection and crop rotation.

EFFECT OF CULTIVATION SYSTEMS AND CROP ROTATION ON WEEDS AND DISEASES OCCURRENCE IN WINTER WHEAT

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The deteriorating economic and energy efficiency as well as environmental considerations require to search for alternative systems of cultivation and plant protection. The replacement of traditional farming systems based on plowing by simplified cultivation increases the interest among the farmers, especially those ones with large farms. They work best in the cultivation of cereals and legumes. A proper sequence of crops is of great importance especially in reduced tillage. The use of reduced tillage in simplified crop rotations may cause an increase in the risk of the infestation with certain weed species, as well as the incidence of diseases and pests.

Three year static long-term experiment was established in the autumn of 2011 in the Institute of Plant Protection. The aim of the studies was to assess the impact of cultivation systems and crop rotation on the incidence of wheat pests as well as the yield of winter wheat. The first tested factor was a tillage system: a_1 – reduced tillage; a_2 – ploughing. The second tested factor was a place of winter wheat in crop rotation: b_1 – winter wheat (forecrop: winter wheat, fore-forecrop: winter oilseed rape); b_2 – winter wheat (forecrop: winter oilseed rape, fore-forecrop: spring wheat); b_3 (integrated system) – winter wheat (forecrop: winter oilseed rape, fore-forecrop: narrow-leaved lupine). In the levels b_1 and b_2 the only one variety of wheat (Legend) was sown but in b_3 a mixture of two varieties (Legend + Ostroga) were used. For both cultivation systems a_1 and a_2 the same level of protection against pests (TFI value) was used. Within the second tested factor the protection level (TFI) varied as follows: $b_1 = b_2 > b_3$. Weed control for b_1 and b_2 was based on the use of herbicides in autumn (TFI = 1.0), and in b_3, autumn harrowing and spring herbicide treatment (TFI = 0.4) were applied.

In the third year after the full rotation cycle it was reported a significant effect of the cultivation system and crop rotation on the occurrence of weed diseases and the level of weed infestation as well as wheat yield and its quality parameters. Within broad-leaved weeds the following species were dominant: *Centaurea cyanus* and *Matricaria inodora* and in the case of grass weed species: *Elymus repens* and *Apera spica-venti* were the most frequent. Weed infestation in the reduced tillage system was significantly higher as compared to ploughing cultivation. The total cover by weeds was as follows: for the reduced tillage system (a_1): b_1 = 55.9%; b_2 = 18.6%, b_3 = 0.6%: for the ploughing cultivation system (a_2): b_1 = 38.8%; b_2 = 8.0%, b_3 = (0.1%).

During the experiment we also observed fungal diseases on wheat leaves, spikes, culm bases and roots. During the observation at the heading stage (BBCH 55) the flag leaf was infected by the casual agents of brown rust (*Puccinia recondita*) and septoria on leaves (*Mycospharella graminicola* and *Phaeosphaeria nodorum*). Winter wheat cultivated in the conventional system a_2 (both in crop rotation and monoculture) in reduced tillage was more infested by the fungal pathogens causing Fusarium foot rot in the culm bases and roots than wheat grown in the tillage cultivation system. The smallest number of infested plants with symptoms of this disease was observed for the integrated system (b_3), both for reduced tillage and ploughing. In the case of Fusarium head blight, the smallest number of plants infested by *Fusarium* spp. was observed in the combination with the integrated system (b_3), with the use of ploughing.

The level of yield obtained in cultivation system with ploughing was significantly higher as compared to the reduced tillage system. The increase in crop diversification had a beneficial effect on wheat yield and its quality parameters (the higher the protein content, gluten, weight of 1000 grains).

SYNOPS-WEB, AN EASY-TO-USE ONLINE TOOL TO ASSESS ENVIRONMENTAL RISK

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During the EU-FP7 funded project PURE (http://www.pure-ipm.eu) SYNOPS-WEB was developed as easy to use online-tool, which enables producers, advisors, policy makers and other stakeholders to evaluate and compare the potential environmental risk of pesticide application scenarios under realistic environmental site conditions.

SYNOPS-WEB consists of a web-based Graphical User Interface (GUI) with an embedded GIS application, a model application service including the Model Core Library (MCL), and a SQL-Database to store entered site and application scenarios, including all necessary information on environmental conditions and pesticides. These three components are linked by XML-interfaces.

The tool was developed based on the established indicator model SYNOPS, which evaluates the potential risk of chemical plant protection products for both terrestrial and aquatic organisms. It combines data of pesticides with their application conditions and their inherent properties, and then calculates the predicted environmental concentration on daily basis for soil and surface waters. In order to assess the environmental risk of a certain plant protection strategy, the user has to follow a stepped approach. Step 1: Define site scenario. The input data for the environmental scenarios are derived from EU-wide GIS maps for soil, climate and elevation. For the surface water parameters and the connectivity to surface water fixed scenarios are entered manually in the tool. Also the selection of drift reducing elements is possible. Step 2: Define pesticide application scenario. For each country two scenarios were assessed: a baseline system based on common practices in the concerned area and an innovative IPM control strategy. Step 3: The tool then combines site- and application scenario's to calculate the environmental risk.

Within the PURE project SYNOPS-WEB was used in fife work packages to assess the environmental risk of the developed IPM strategies.

LANDSCAPE AND CROP COMPOSITION TO PROMOTE GENERALIST PREDATORS IN AN ARABLE SYSTEM

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It is well known that landscape composition and structure effect biodiversity including important functional groups in managed lands. Many studies highlight the positive relationship between landscape complexity and ecosystem services agents such as natural enemies. Semi-natural habitat has been considered the main determinant of complexity in agricultural landscapes. However, this approach frequently does not consider different types of semi-natural habitat while also omitting any consideration of the crops being grown, neglecting possible monoculture/polyculture effects. As a response, this study aimed to reveal detail elements of the landscape composition that favour generalist predators and to distinguish the most important drivers amongst them.

To test this, pitfall traps were placed in the margin and within the crop of 40 fields in the east of Scotland to sample the population of three main groups of generalist predators (Carabidae, Araneae and Staphylinidae). To assess the relative importance of landscape composition, we used a multi-model analysis approach taking into consideration local, boundary and landscape characteristics. Landscape composition was characterized in three ways and at several scales (500 m to 5 km radius), from a simple differentiation of habitat structure (arable, semi-natural, woodland) to more detailed characterisations, one differentiating the most abundant semi-natural and woodland types and the other directed to describe more precisely the arable land by the most common crops considering their differences on management intensity, ecological functionality and habitat structure.

In this study we found that landscape composition has a significant effect on population of predators, and in some cases was of greater importance than local variables. As a general trend, our results show that the generalist predators considered respond positively to broadleaf woodland and heath, and mainly at larger scales. The response to crop composition tended to be less consistent between the different groups, although a significant effect of crop composition was found for each group. We also found different responses to local and landscape variables between margin and crop populations, suggesting that they may respond to different drivers.

These findings add to our understanding of the influence of the agricultural landscape on important ecosystem services agents of the cropping systems, contributing to the assessment and development of the land management policies.

AGBIOSCAPE: COMPUTER SIMULATION SOFTWARE FOR MODELLING THE DYNAMICS OF POPULATIONS IN FARMED LANDSCAPES 79

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The movement and dispersal of organisms across farmland exposes them to a range of habitats within the agricultural landscape. The effect of this is on natural populations is demonstrable with a wide range of taxa including weeds, insects showing responses in both diversity and abundance to a variety of landscape characteristics. Though empirical studies have been important in demonstrating landscape scale effects and have even begun to unravel some the underlying mechanisms, appropriate modelling strategies have a number of important advantages. These include:

- Addressing spatial and temporal scale beyond the practical limits of any empirical study.
- Addressing a wide range of landscapes, cropping systems, and taxa.
- Simulation of novel landscapes and landscape management strategies for which no examples currently exist.
- Addressing complex multi-trophic systems.
- Provide results within a short-time frame.

With these benefits in mind we have developed AgBioscape, computer simulation software designed for the implementation of spatially explicit population models within farmed landscapes.

The AgBioscape modelling system couples discrete time population models with an explicit representation of the farmed landscape using two primary software modules: the landscape mosaic generator and population process module.

The land use mosaic generator works by continually subdividing a 2-d space to produce a network of rectangular land parcels, the size, shape and clustering of which can be controlled. After generating a mosaic of fields, a series of land uses is assigned to each, allowing users to specify how the landscape changes over time in response to crop rotation or other land use changes.

The population process module uses a matrix population model approach to simulate the population dynamics of each local population. Local populations are arranged spatially on regular grids, one grid for each species being modelled, which are overlaid on the land use mosaic. Each grid-cell holds a numerical vector representing the stage structure of a local population, while transition matrices are used to specify the demographic changes in stage structure that occur over time as a function of intra- and inter-specific interactions, as well as the prevailing habitat and environmental conditions that are derived from the land use mosaic.

Dispersal between local populations is modelled empirically using dispersal kernels. These can be extended to represent complex dispersal processes by combining kernels, either in single or multi-stage dispersal events, or by the inclusion of attraction or repulsion responses to represent active dispersal.

The development of several models in AgBioscape has confirmed the utility of this approach and shown it to be capable of representing a wide range of pests, crops and landscapes.

EUROPEAN CORN BORER THERESHOLDS FOR MAIZE IN INTEGRATED PEST MANAGEMENT: A WEB-BASED APPLICATION 80

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One of the main parameters needed to implement **Integrated Pest Management** (IPM) are the economic thresholds. Currently, there are no economic threshold to implement IPM for *Ostrinia nubilalis*, the European Corn Borer (ECB), a major maize pest. In order to assess practical economic thresholds for ECB in maize, we built a large database containing phenological pest information (e.g. adults captured with light traps during the swarming period), maize phenology, crop damage and yields. Data were collected in various maize cultivation areas of the Veneto Region over many years. Experimental activity also covered other objectives, such as timing of insecticide application, efficacy of active ingredients (including organic ones) and biological control with parasitoids. The database was used to develop and calibrate models of a software platform fed with data from the weather stations of the Veneto's regional meteorological service operating at local level.
The software platform includes a crop model for maize (CropSyst), which is coupled with an ECB phenology model and a management model. The software platform is linked to a web application and a user interface. Users are taken through the steps of a decision-making process that leads to a recommendation as to whether control is needed. The phenology model predicts egg-laying times, as well as the evolution of larvae population. This information can be used to identify optimal scouting times for insect development stages and then to establish thresholds.
The current model includes the essential costs of applying insecticides, as well as estimated final borer populations for each plant stage, predicted yield and yield-loss values for each population, and estimated percentage control achieved by the insecticide. The computerized management model involves two separate steps:
1) calculating an economic threshold (E_Th);
2) comparing E_Th with Potential Pest Density (PPD).

Step 1 requires the real insect-pressure data. The main indicators chosen are the mean plant egg masses density (mainly used by experienced technicians or advanced growers) and the percentage of ears showing signs of ECB larvae presence during middle-late silk phase (the scouting to be done is less time consuming than that for egg masses). Step 2 is then computed according to the indicator available. The model first indicates the "indifference" threshold, which is the point where ECB pressure is not likely to cause any yield reduction. The second threshold is the economic one, i.e. the point where the costs associated with applying insecticide equals the estimated value of the yield loss if control measures would not be taken. PPD is computed as the number of borers surviving the damaging stage.

Research conducted also within the European Project PURE

MUTUAL FUNDS ARE A KEY TOOL FOR IPM IMPLEMENTATION: A CASE STUDY OF SOIL INSECTICIDES IN MAIZE SHOWS THE WAY

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Integrated Pest Management (IPM) may cause risks of crop damage, especially when it is implemented for the first time and when farmers are inexperienced. The risks apply mainly to arable crops, as IPM strategies have not been used extensively on them. Therefore a simple, reliable tool that compensate mistakes in IPM implementation may help avoid any decrease in cultivation net income and make farmers more comfortable with IPM implementation. Mutual funds, i.e. farmer-managed no-profit insurance tools, are an effective solution. They cover risks that private insurance companies currently do not (e.g. climatic adversities, such as flooding and damage by wild animals and pests, just before and after the emergence of arable crops). When the damage risk is low, mutual funds cost less than large-scale pesticide use. The lower the damage risk, the more convenient a mutual fund becomes, even without EU funding. This funding, which is based on EU legislation, may cover a significant part of the financial compensation for damaged fields, making mutual funds far more convenient. This approach has been implemented for soil insecticides in maize in Italy. Long-term data suggest that the majority of Italy's maize farmland does not need to be protected with insecticides at sowing. Indeed, the percentage of land with high populations of wireworms (a major soil pest in maize farmland) is often very low (e.g. less than 5% in the Veneto region, an area with large-scale maize production). At European level, the PURE project has produced similar results. After four years of monitoring, no significant wireworm/other soil-pest damage in the experimental maize fields of France, Hungary, Slovenia, Germany and other Italian regions was detected. Hundreds of plots have been examined in studies from Italy, and in the large majority of the experiments there were no statistically significant differences, in terms of yield between maize treated with soil insecticides and non-treated plots because of low wireworm damage and/or the compensation capacity of the crops. Because of this general low risk level, a crop insurance program where growers may purchase insurance, instead of soil insecticides to provide financial compensation when yield losses can be attributed to pests would be more convenient than insecticide protection on large scale. The total cost of damage to maize (need of re-sowing and yield loss due to delayed sowing or reduced stand) is often much lower than the total cost of the soil insecticide treatments of most fields. Furthermore, it does not consider the environmental side effects of insecticides. Therefore the successful approach is to implement IPM in accordance with Directive 2009/128/EC as follows:

a) risk evaluation: the factors that increase the risk of soil-pest damage have been studied analyzing a comprehensive database built up over 30 years, correlating soil-pest damage with a vast range of agronomic, climatic and pest information. The main information includes: type of the main soil pest; organic-matter content (>5% significant risk increase); and type of previous crops;
b) no risk factors greatly decrease the chance of economic damage and make the application of soil insecticides in most fields useless. Where risk factors are present, it is good practice to assess wireworm populations with bait traps and to introduce control strategies only when and where economic thresholds for maize are exceeded. Mutual funds cover the risk of mistakes in IPM is implementation, including any underestimation in the size of the area with wireworm economic populations.

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