STRATEGIC RESEARCH AGENDA FOR IPM IN EUROPE

Revised draft document

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This draft document, prepared by the ERA-NET C-IPM, may yet contain imperfections. C-IPM consider it essential to leave sufficient time for further feedback so that it can be useful in the elaboration of the final document due end of 2015. Comments from C-IPM partners and a wide range of stakeholders have been considered to prepare an improved version of a Strategic Research Agenda for IPM in Europe.

Summary outline

The Strategic Research agenda (SRA) of the European Research Area Network of Coordinated Integrated Pest Management (ERA-Net C-IPM) is designed to address the key concerns of better coordination of national research efforts to enhance IPM implementation. Concerning the challenges for agriculture and crop production it will provide recommendations on future European and national research. The content of this SRA is taking into account the previous initiative of the Standing Committee of Agricultural Research Collaborative Working Group (SCAR CWG) on Integrated Pest Management (2011-2014) and the outcomes of mapping national research priorities and needs as well as workshops on national research programmes and infrastructures performed within the C-IPM.

The ERA-NET C-IPM is the first transnational network of research programme owners and managers, funded by the EU that aims to align national research programs on IPM in Europe. Thirty two organisations belonging to 21 EU-Member States (MS) and Associated Countries are collaborating in this network. In order to cope with the common future challenges encountered in European agriculture the ERA-Net C-IPM aims to play a central role by coordinating joint research and transnational calls concerned with Integrated Pest Management especially in support of the policy requirements established by the Directive on the Sustainable Use of Pesticides (Directive 2009/128/EC and the Regulation on placing plant protection products on the market (1107/2009/EC).

The overall objective of the C-IPM SRA is to delineate both short to medium as well as long term priorities for IPM research, identify gaps and enable enhanced IPM uptake in Europe. The short – term agenda aims to create a forum for exchange and identification of IPM research and development priorities, connect existing initiatives, and coordinate joint transnational research calls. The SRA will lay the groundwork for the implementation of joint transnational research.

In this context, the SRA has the following specific objectives:

- Support/network IPM-related research and create synergies based on a *status quo* survey of existing research activities on IPM within the EU;
- Identify overlaps and gaps to avoid duplications as well as identify opportunities for better coordination and joint initiatives on research;
- Enhance pre-existing and establish new linkages between research programmes and initiatives towards coordination of IPM research and development (R&D) in Europe;
- Identify future challenges for European crop protection which requires IPM solutions;
- Feed emerging research demands to meet these challenges into the Horizon 2020 framework program;
- Identify opportunities and mechanisms for knowledge transfer/sharing; training & dissemination of information of IPM research.

Introduction

Today's agriculture faces multiple challenges: foremost ensuring food security by a highly efficient and sustainable plant production. Crop protection and IPM are cornerstones of preventing crop losses and ensuring high quality production.

What is IPM?

Integrated pest management (IPM) means careful consideration of all available plant protection methods and subsequent integration of appropriate measures that discourage the development of populations of harmful organisms and keep the use of plant protection products and other forms of intervention to levels that are economically and ecologically justified and reduce or minimise risks to human health and the environment. IPM emphasises the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms (European Commission 2009). Priority is given to prevention and non-chemical methods while chemical solutions are adopted only when their use is indispensable. In this way, IPM aims at assuring economic and ecological sustainability of cropping systems.

IPM is a dynamic approach, hence a continuously improving process in which innovative solutions are integrated and locally adapted as they emerge and contribute to reducing reliance on pesticides in agricultural systems. Such improvements derive from the fact that the approach responds to diverse farming situations. An optimal decision process is based on sound knowledge of the entire cropping system and available information and tools which need to be combined or to be improved. These flexibilities and resilience in space and in time enrich IPM power making it an ideal approach for pest management and even integrated crop management.

European legislation and the challenges for sustainable agriculture

Most of the current pest management practices in Europe are mainly based on the use of pesticides. However, management alternatives to broaden the suite of applicable tools beyond the use of synthetic chemicals have been sought due to increasing awareness concerning the possible negative impacts of pesticides on human health and the environment. Consequently, the European Commission introduced legislation on reducing the risks and impacts of pesticide use on human health and the environment.

The Directive on the sustainable use of pesticides (2009/128/EC) requires from European MS to set up National Action Plans to define objectives and measures to achieve risk reduction during the use phase of pesticides. Moreover, according to Article 14 of the Directive (2009/128/EC) (European Commission 2009b), all professional users of pesticides have to apply the general principles of IPM, as laid down in Annex III, since 1 January 2014.

EU Regulation on placing of plant protection products (PPP) on the market (Reg. 1107/2009/EU) sets out the rules for a harmonised approach to regulate the authorisation based on harmonised data requirements responding to risks concerning human health and the environment. This is likely to reduce the availability of a number of pesticides previously used in European agriculture. In addition, the broad European re-evaluation of pesticides initiated in 1991 resulted in the withdrawal of 73% of the pesticides up to now.

Increased public awareness and societal demands about the potential risks of pesticides resulted in the review of previously authorised pesticides. In addition, the number of new active compounds entering the market decrease and a reduction of 10 to 40% of the currently available PPP is expected to in the coming ten years and thereby further increase the demand for alternative and feasible plant protection approaches and solutions, as offered by IPM methods.

Overall, European agriculture currently faces two major challenges. Firstly, for many crop/pest situations, no effective and economically feasible alternatives to synthetic pesticides are yet sufficiently available or still under development. Hence, there is a need to put more effort in developing IPM strategies that significantly reduce reliance on the use synthetic pesticide while maintaining crop yield and profitability. Secondly, in a number of cases, a range of IPM tools are available but their adoption remains still a challenge due to different climate, soils, cropping and farming systems. Regional differences disproportionate pest risks and the effectiveness of IPM across Europe thereby resulting in significant losses of production in specific areas. Highly diverse crop production systems across Europe, with even more diverse geographic and climatic conditions, increase the complexity in European crop protection. The competitiveness of European crop production can be challenged due to the decreasing number of available pesticides coupled with the related reduction in pesticide development by manufacturers. This could put EU production at a disadvantage compared to EU competitors and requires research to foster and support IPM. Hence, ensuring a stable crop yield and quality and concurrently reduce the reliance on pesticides is a huge challenge that research and the farming community are facing.

The role of Policy

The recent focus on sustainable and environmentally friendly agricultural production, the introduction of greening measures and agro-environmental measures in the rural development programme might act as leverage for public awareness of the environmental actions of the farmers. Agri-environmental climate measures can be a means to voluntarily encourage farmers to environmental commitment and farming methods beyond legal obligations. Such additional measures can also be developed directly for IPM purposes (e.g. useful plants for pest control as trap plants, shelter and food/host source for beneficial arthropods, etc.).

During this paradigm-shift in European agricultural policy, it is unclear how readily IPM approaches and crop-specific strategies will be adopted, especially whilst knowledge and technology gaps still exist (Lefèbvre et al 2015). While adoption of the general principles of IPM is mandatory in Europe, adoption of crop specific guidelines is voluntary. It means that it is not obligatory for farmers to adopt IPM which increases the risk of its slow adoption. Moreover, there is a high heterogeneity in level of commitments among the MS. The interpretation and fulfilment of the principles and the possibilities of the IPM principles' implementation into practice vary due to climatic and agricultural conditions but also due to existing knowledge and experience with IPM. In this regard, understanding drivers of change, and how rapidly a transition in the crop protection paradigm from conventional to an IPM basis can be pragmatically achieved is of interest. Understanding the drivers of IPM adoption requires a broader and multidisciplinary approach since IPM covers a large set of principles and is, by far, not solely limited to reducing pesticide use.

A better understanding of the obstacles related to IPM implementation should be the focus of policy. Is IPM more costly than synthetic chemicals? Even if IPM measures do not cost more, not every farmer is willing to use them, often due to risk perception or habits. Costs are the most important driver to (not) implement IPM but risk perception, the social environment of the farmer and the public opinion are also important drivers in the choice of plant protection measures. Answers to the questions "how to manage and influence these more soft factors" are central to the success of the evolution of farming towards the sustainable use of pesticides and to encourage the development of adequate policies to improve the level of IPM implementation throughout the MS where IPM is not fully developed and implemented.

Consumers and communication

Consumers are a stakeholder group which partially impacts on production schemes and market opportunities from the buyers' perspective. Public opinion is not balanced concerning crop protection issues and rather based on perceived risks and limited knowledge on food production as a whole. The purchasing behaviour of consumers, does not reflect the attitudes and concerns of the public on environmental effects from agricultural production. In reality, consumers choose by price rather than sustainability of the production system, visual criteria rather than taste and unspecified "quality" rather than by products certified as organic or sustainable production or transport. This is due to lack of knowledge or lack of interest and budget possibilities. If the increased focus on IPM is extended to the consumers, in addition to the producers, there is a need for producers to actively engage with the retail sector to take this into consideration in their assortments.

The retail chains and in particular supermarkets have an important role to play in encouraging IPM. Overall, retail chains currently represent a constraint on IPM because of their demand for zero maximum residue level (MRL) or below the legal thresholds as well as the blemish-free and cosmetic quality. The MRL requirements can be counterproductive to the IPM concept with regard to resistance management, use of selective pesticides, the use of treatment thresholds and environmental sustainability. Therefore there is a need for considerable engagement for trainings and communication with both retail chain partners and consumers. It is important for the farming community to engage in the public discussion with facts about sustainable production to ensure a broad and multidirectional discussion.

As retail chains have a stake and potentially strong influence on production schemes, besides MRL, other demands to the purchasing of products like environmentally sound production and ecological or carbon footprints per unit of product can be of relevance. These trends are opportunities for implementing IPM.

Better information and education on IPM approaches and its value in sustainable production is of importance to overcome perceived risk and better understanding of the production process for all concerned groups. The general public, including children at schools; should be well-informed about food production methods, the difficulties and the needs with regard to plant protection measures. Farmers and researchers can make more use of demonstration fields and field days to create an understanding for food production. The real risk vs. the perceived risks of consumers should be explained by science in "easy-to-understand" messages. All possible communication channels and media should be engaged to producing clear and simple messages for the general public.

Development of a label or indicator for IPM could be useful to increase the IPM visibility. A simple indicator which informs on the societal, environmental and economic benefits could help to create an understanding; e.g. for environmental view, eco-toxicity and other footprints could be used as an indicator compared to the carbon footprint or usage of harmonised environmental risk indicators.

The role of research

Success of IPM will depend on the provision of novel, effective and reliable approaches and tools to the farmers. IPM is the systematic combination of cultural measures and a range of innovative tools which increasingly will need to be implemented or improved by joint approaches of the farming and scientific community. Other innovative tools still need to be developed and/or further advanced to become ready for use by research.

Short term consequences of the farmer's choice are often critical for the decisions in practical management, but more focus on the long term consequences, e.g. of resistance development, might benefit IPM solutions. A better communication of the benefits of IPM, based on actual data on benefits in the region in question, could help more farmers to implement a high level of IPM. Socio-economic research might play an important role to this objective.

Far-sighted research that focuses on the anticipation of future risks and development of sustainable systems to avoid deadlock pest problems and to prevent crop pests does not still exist. To this aim, breaking of barriers between disciplines and the establishment of a more wide-ranging perspective that embraces the ecology, biology and evolution of pests and the capacity to evaluate the risk and make clear predictions; are needed.

The transfer of knowledge from research results to practical management is often hindered especially when practical implementation issues are not considered. Research driven by practical questions can help overcome such obstacles. Farmers face complex crop management and crop protection issues, including the multiple interactions between crop nutrition, crop growth and pest development. Therefore research should not only be limited to the different partial aspects of pest control, nutrition, etc. but also look especially at interactions. In some countries the scope is broadened and IPM is put in resilient and sustainable systems. Knowledge exchange, focused on the whole production chain, allows farmers to have a better basis for the implementation of IPM.

Farmers should be ensured that the available knowledge is accessible to them. MS increase their efforts to overcome the gap between research and practical management. Advisory services have an important role in this process and demonstration farms can contribute to bridge between applied research and farmers. Experiences from employing the principles and practices of co-innovation show that if farmers are effectively involved in the development of new tailor-made solutions the buy-in into changing practice has more impact. There is a need to investigate expansive learning among farmers and other stakeholders to define future research activities/needs and to better understand how the local contingencies – ecological, social, economic and technological – influence the ease and willingness of IPM implementation.

The socio-economic questions of IPM implementation are crucial to the farmer and need to be addressed in research, "in a transversal way", in order to present evidence that the more complex combination of tactics performs equally. Research on IPM should therefore be designed from a multi-actor perspective, and address not only availability of approaches and tools, but also socio-economic factors determining their acceptance. There is a need to analyse the behaviour of professionals and public actors as well as research on the scientific knowledge and technical solutions. To date, there is a lack of an inventory of experiences and research that show how and why the change in practice can take place. To this objective, it could be useful to provide success examples based on local or regional experiences. It also raises questions about the identification of socio-technical and socio-economic impediments and means to cope with it.

Il addition, there is a need to mobilise theoretical frameworks such as the sociology of organisations, institutional economics, and public choice theory. Research exploring socio-economic links between the different actors ranging from pesticide producers to the pesticide users including cooperatives, traders, consultants, unions to consumers are essential to help implement IPM.

In national and European research over the recent years much effort has been invested to generate new knowledge, develop innovative approaches and tools. Nevertheless, this kind of research has been fragmented and addressed via specialised research disciplines. The integration and adaption of available knowledge into the holistic approach of IPM is still insufficient or lacking.

Hence, current IPM research organization is being challenged. Future research should link between generic research and applied practical solutions and increasingly shift from mono-disciplinary to multi-disciplinary system-based approaches **(Fig. 1)**. Farming systems research and research approaches employing theoretical view on systems could provide new insights as they both look at farming as a systemic, socially and materially constructed entity. This kind of IPM research could integrate the multidisciplinary and trans-disciplinary aspects of IPM research. Research should move from "product-based to chain-based and regional approach" and from research driven to question driven. Only choices based on the whole chain or regional needs lead to the successful implementation of IPM. To fill this gap, the role of extension and demonstration farms is of paramount importance as an "interface". The IPM system approach and co-innovation methods are envisioned to better interlink knowledge capacities of farmers, extension and research to generate and advance robust and sustainable solutions and strategies.

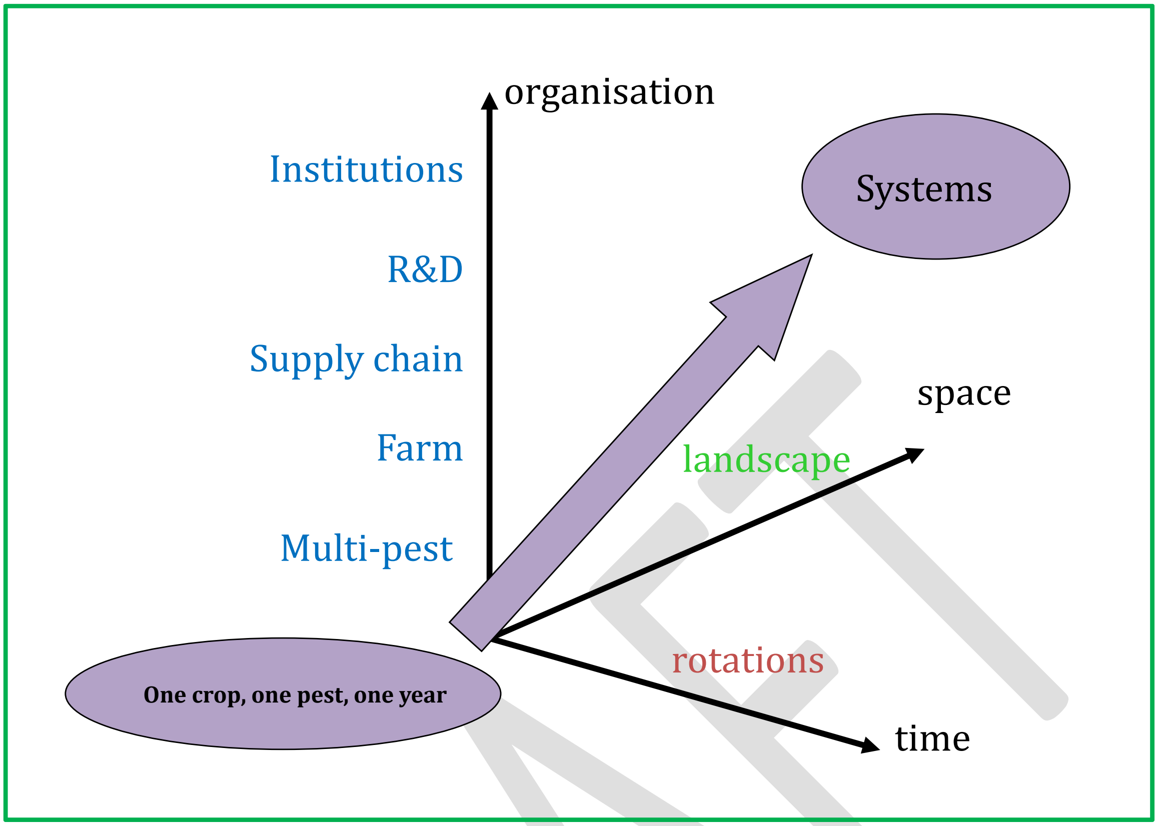

Figure 1. A sociotechnical perspective of the systems challenge

The organisation of research programmes is very diverse and varies between the MS. To avoid overlapping research and make most efficient use of national and European funding, joint trans-national research (JTR) can play a vital role in IPM research development and implementation. There are a number of identified research areas within IPM of common interest at regional, national and trans-national levels. In such cases, JTR is of central importance to benefit from trans-national collaboration and work sharing.

Methodology - inputs to the Strategic Research Agenda

Different activities aim to enforce the C-IPM process and to move toward a trans-disciplinary and participative approach. The analysis of current and future national research programs allowed having an overview of European Scientific Research Agenda. A number of mappings identified needs, gaps, weakness, strength and challenges. All this information led to the development of this SRA. The strategy will be further developed via stakeholder discussions, thematic workshops as well as activities dedicated to the analyses of infrastructure and platforms, capacity building, education and training, knowledge exchange and communication and dissemination. Joint actions and activities are planned to implement the SRA. The progress of C-IPM toward reaching its strategic goals will be monitored, to allow necessary adjustments to the agenda and the means of implementing it. An overview of C-IPM activities that contribute to the SRA is reported in Figure 2.

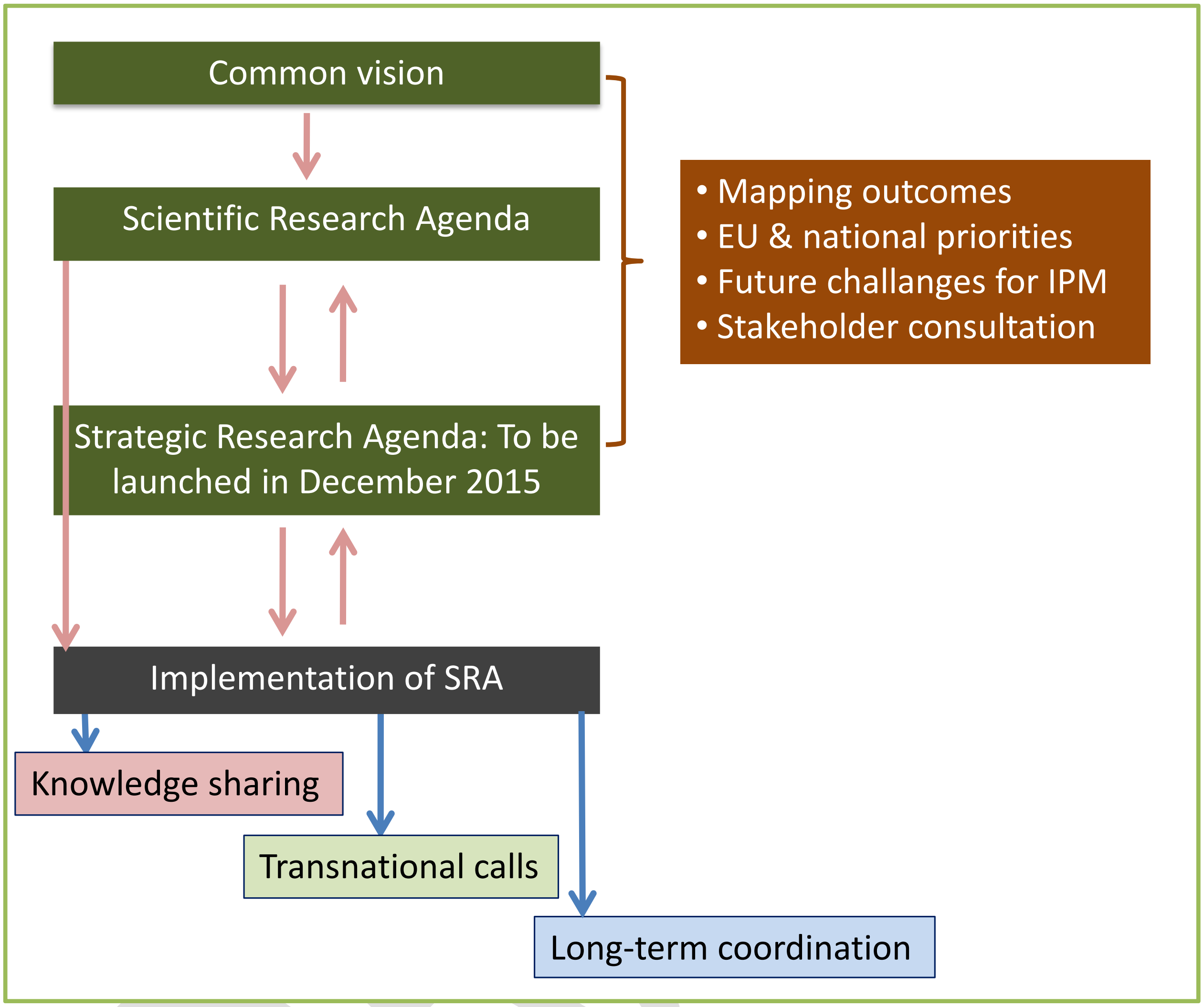

Figure 2. C-IPM activities contributing to the Strategic Research Agenda

Needs and gaps based on the mapping and results of survey

In order to identify and map out existing relevant policies, ongoing research and existing infrastructures of IPM research, extension programs and initiatives, designed to support IPM implementation, a survey among C-IPM partners has been carried out. The goal was to provide information that will serve to identify research and development needed to support National Action Plans (NAPs), and IPM in particular, to assess the added value and opportunity of jointly addressing needs and, finally, to make recommendations on coordinated trans-national research initiatives. Overall, the following points have been identified:

<u>Strength:</u>

- Coordinated research at European level has been emphasised by all partners as essential for the progress of IPM in Europe;

- The need for developing broader projects that could address long-term and future key issues and identify priority subjects has been acknowledged by all partners;
- Sharing of experiences on IPM implementation in practice has been emphasised by all partners. Countries who have implemented IPM for long time have acquired important experiences and are ready to share their experiences with countries where IPM development and implementation are at the initial stage;
- IPM demonstrations farms exist in several MS and offer a good option to engage in a European network.

Weaknesses:

- Decreasing funding for IPM research, little transfer of research knowledge into practice and lack of communication and collaboration among the actors involved in IPM throughout the MS are current problems in Europe that hinder IPM implementation;
- Short term and project-based funding prevails and does not support the development of IPM farming systems. Long-term funding aimed to feed long-term experiments and demonstration and/or reference farms are needed;
- The socio-economics of IPM implementation - including the role of value chain partners (food processing and retail), the social environment (advisors and colleagues), public opinion (activist and moderate NGOs) and farming styles (value chain oriented, agronomy oriented, equipment oriented) of farmers and growers – is yet very poorly addressed and there is an immediate need to focus on these aspects.

Based on the mapping and discussion with C-IPM partners a number of global challenges in terms of IPM development and implementation were identified (table 1).

Table 1. Short to medium and long term global challenges identified across Europe

Challenges	
Short to medium term	- Develop alternative pest control methods to pesticides - Address pest control in minor crops through the development of sustainable solutions - Foster European networking of existing demonstration farms
Long term	- Develop robust intermediate interfaces both at farm and scientific levels to link research and practical problems - Develop system experiments to feed holistic research approaches - Design bottom-up organisation of applied research through fundamental research

Stakeholders

The view and contribution of stakeholders on the ERA-Net C-IPM is of fundamental importance to achieve the goals of the SRA. To this aim 267 different Resource Groups (RG) in eight C-IPM RG Categories have been identified. The RG Categories comprise research funders, research managers, national-, regional-, and transnational research networks, transnational plant protection related organizations, research providers, SUD-FRAMEWORK implementing authorities, advisory and extension services, organisations/associations of farmers, consumers and industry. The members of RG will be on a case by case basis either invited to actively contribute to C-IPM, be consulted or informed about activities and processes.

Strategic Research Agenda

In order to identify the priority topics related to IPM research, surveys were conducted within the C-IPM. Based on the outcomes of these surveys, a long list of potential research topics was prepared and further discussed during the C-IPM annual meeting (Annex 1). Based on the feedback provided by C-IPM partners, the most important topics have been categorised in 4 core-themes (Figure 3). Each core theme includes more than one topics and several sub-topics (See Annex 1). These core themes include topics that reflect the current priorities and future research needs of the partners and consequently represent short to mid-term IPM priorities.

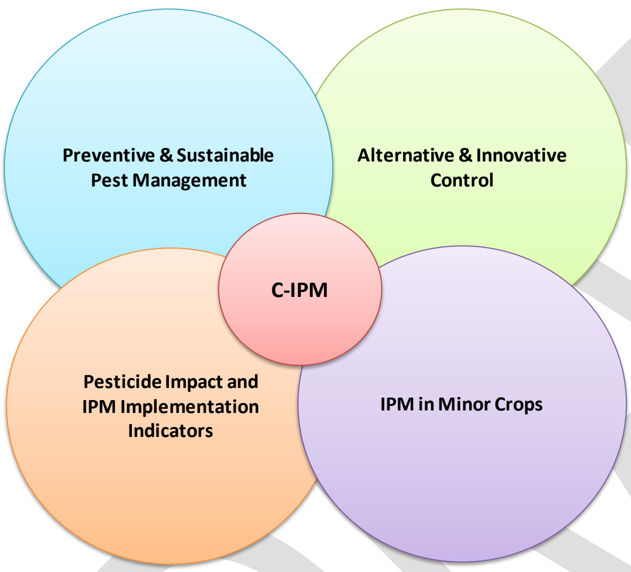

Figure 3. Four core themes

Core theme A: Preventive and sustainable (pest) management

Background:

Effective and sustainable cropping systems can be defined as those in which the input to control pests is reduced as much as possible. A substantial reduction is feasible only by integrating a range of strategies that help prevent pest establishment and consequent losses due to pest. Interventions, based on chemical control, into cropping systems are effective only for short term relief. Long term solutions can be achieved only by restructuring and managing these systems in ways that maximise the array of "built-in" preventive strengths, with chemical tactics serving strictly as backups to these preventive measures. Hence, a total system approach based on prevention is essential as the guiding premise of pest management.

Integrated solutions for crop protection, that integrate application of new technology, risk mitigation measures, crop management to increase and favour the resilience of the agrosystem, development of low input systems, application of low risk plant protection products, are needed since they contribute to decrease the use of conventional PPP and to implement innovative IPM solutions. Many agronomic/cultural approaches may prove beneficial as a single strategy or as part of an integrated systems approach. For example, choice of variety, time of sowing, seeding rate (plant density), nitrogen management etc. warrant further research either as single factors, or particularly as part of systems which could reduce the need for pesticide input. Similarly, soil cultivation systems may impact on disease/pest carryover from season to season.

Genetic improvement of plants, to acquire greater resilience and resistance, can be accomplished by more precise and rapid breeding techniques, such as marker-assisted selection. For example, disease resistance can be engineered based on advances in understanding the plant immune system (Dangl et al 2013). Pyramiding resistance genes combined with monitoring of the occurrence of new virulence genes in pathogen populations under field conditions will be the basis for future durable resistance management, and a key for advanced IPM. Deployment of pest resistant and/or tolerant plant genotypes to pests at landscape level is one of the key levers for the reduction of pesticide reliance in agriculture. This approach also represents the most robust one among the IPM tools, given its direct impact in avoiding and or/containing yield losses. The importance of considering resistance durability in a landscape context has received increasing emphasis (Mundt, 2014) and is an important future area of research. Experimental systems are being developed to test resistance gene deployment strategies that previously could be addressed only with logic and observation. Questions such as how to design pest suppressive landscapes that are environmentally sustainable and how to get land managers to collaborate need to be addressed. For this reason, there needs a focus on socio-economic aspects.

Although the use of resistant cultivars is an important tool for pest management a widespread use of such cultivars is hindered as the number of cultivars that possess high levels of resistance to key pests is very limited. This is mainly due to the fact that, a highly resistant cultivars to a given pest may result markedly susceptible to another pest or result in a yield penalty. However, such constraints could be overcome by using new technology. For example, the application of recombinant DNA technology to genetically engineer insect-resistant crop plants has provided a way to eliminate this constraint and make host plant resistance a potential component of IPM in major cropping systems world-wide (Kennedy 2008). Likewise, a range of genetically engineered herbicide resistant crops are available on the market which need to be integrated to the IPM toolbox. Such crops offer the greatest potential to contribute to the establishment of sustainable crop protection systems only when they are integrated within the framework of IPM, rather than applied as "a stand-alone pest control measure".

Reducing the use of pesticides requires a better knowledge of pest population dynamics, including the possible impact of antagonist, as well as of economic threshold values. Such information is essential when developing IPM strategies and in decision-making related to pesticide treatments. It is not possible to minimise the use of chemicals in agriculture without effective early warning systems based on the forecasting damages by pests. Such information is necessary also to evaluate economic feasibility of a given intervention. Early warnings and forecasts allow time for managing incoming pest attacks and can thus minimise crop loss, optimise pest control and reduce the cost of cultivation. Crop yields and net returns can be maximised by using prevailing and anticipated weather information, which can help in crop planning and spray scheduling and other farm operations. Furthermore, the weather information can also help minimise the use of pesticides.

To this end, decision support systems (DSSs) have been emerging as essential tools to bridge the gap between science-based technology and farmers who make day-to-day management decisions. Web-based models and DSS may be an absolute future requirement for an effective implementation of IPM in Europe, provided that farmers are encouraged to adopt such tools. DSSs are an important tool to take strategic decisions for pest control even under complex and uncertain conditions (Shtienberg 2013) with direct and concrete implication in terms of pest control and significant reduction on the reliance of synthetic pesticides. Effective implementation of DSSs requires efficient pest monitoring systems in order to assess the actual pest profile and pest pressure at different spatial and temporal scales. Although the organization and the scientific basis of existing pest monitoring systems/DSSs widely vary from the type of pest problems and countries, there exist many similarities between European Member States in terms of crops and pests, the content of information conveyed to farmers and among the organisation of the communication systems.

Recent advances on molecular technologies for detecting and identifying pests offers new perspectives in this regard which could greatly improve the accuracy and efficiency of existing pest monitoring systems. Pest forecasting - including population dynamics, improvement and validation of models based on field observations - includes research on the pest biology, their life-cycle and the key factors that could limit their populations. Several current DSSs are negatively affected due to the limited number of observation points for most pest monitoring systems and their use to predict the risk in a given area. To overcome these constraints, epidemiological models may play an important role and there is a need to put more efforts in this regards. There should be a clear understanding on the biotic and abiotic co-variables to be collected and used to redress this sampling, extrapolate the results to other situations and to predict the local level of risk and thus to support tactical or strategic decision-making. A redefinition of "old" threshold values is needed in the context of the actual production systems (resistance traits of the actual variety set, market, available control methods, compensatory ability of crops according to the actual agricultural practices etc.), with regional and transnational perspectives. The concept of threshold levels - commonly used in current DSSs - should be extended to better understand the effect of the environment and agricultural practices while predicting damages. The relevance of such threshold levels widely depends on the context of their use, particularly in crop protection strategies implemented at the cropping system scale.

Crop loss assessment due to pests is another important factor to be taken into account. Reliable estimates of economic losses caused by pests are indispensable both for optimal crop management at the farm level as well as for basic decisions on broader issues such as research priorities and pesticide use. Crop-loss assessments have been made for major annual staple and cash crops (Oerke, 2005) although data inadequacies are particularly acute in the case of perennial crops. The concept of economic thresholds are rarely based on rigorous quantitative estimates of how pest numbers at different crop growth stages are related to resulting yield, and as importantly, to quality. Such thresholds also fail to take into account crop physiology and the ability of crop plants to compensate for damage at different growth stages.

Assessment of this core theme through the survey highlighted the following research needs:

- Engage in research on prevention as main IPM resource tool and core of resilient cropping systems;
- Cropping systems should be as much diversified as possible. To this aim, crop rotation, intercropping and use of cultivar mixtures need to be adopted;
- The development of robust and resilient cropping systems is required to ensure long term competitiveness of European agriculture based on sustainable solutions;
- New phenotyping, new screening methods and markets need to be developed in order to breed varieties that could match with the needs that we have today by taking into account the specific climatic conditions of Europe since the main focus on standard varieties is less likely to adaptable throughout the European range. To this objective public-private partnership is essential;
- Currently available tools for early detection and identification of pathogens from seed and propagation materials need to be improved to increase their sensitivity and their specificity;
- Existing tools for qualitative and quantitative monitoring of soil and substrate pests have to be integrated, to be able to know the health status of the culture substrate as input for the choice of the crop/cultivar (= advanced crop rotation);
- Pest monitoring, surveillance and forecasting are among the prioritised topics in the NAP of all MS. Hence, there is a need to establish the necessary scientific infrastructure and scientific advisory capabilities to support modernisation of the monitoring and regulatory systems for pests, based on rapid developments in diagnostic, information technology, modelling, and communication methodologies. ;
- Pest monitoring systems made to date are on a species by species case, whereas farmers need to handle a multitude and a combination of pest species that occur in different crops. For this reason, there is a need to develop, improve and implement such systems at broad level and work at large scale (landscape level) besides at crop or field level. Besides the agricultural areas "*in sensu stricto*" pest monitoring should be performed "*in sensu lato*" including non-agricultural areas which are often the potential reservoirs of pests. Monitoring technologies need to be improved to be able to monitor the virulence spectrum and the emerging of new virulence genes in field populations of the pests;
- Further development of the practical value of the knowledge on that endophytes - naturally occurring micro-organisms in each plant - play a role in the natural immunity of plant against pests. Seeds and planting material might be excellent sources for introducing endophytes leading to more resilient plants during the whole cropping stage;
- Strategies need to be developed to introduce sustainable resistance (R-gene stacking, S-genes etc.). More effort is needed to put in place strategies for durable resistance management (preventing R-breaking) and resistance breeding for competition with

weeds. Research on physiologically important genes as input for breeding for new plant phenotypes less vulnerable for infection than the current cultivars is needed;

- EU-regional-wide harmonised monitoring and forecasting systems at field and landscape levels are needed for those regions that face the common problems. Integration, improvement and implementation of all available tools and solutions for DSS is an overarching requirement;
- Web-based tools should be implemented in such a way to share data coming from the harmonised monitoring activities carried out in different areas of Europe and by different actors (growers, advisors, etc.). Initiatives are needed to generate European data;
- DSSs in a broader context should be the priority for research than single pest/crop association; e.g. considering farm level, production site, resistance management, global change, landscape biodiversity;
- Socio-economic aspects, such as end-users behaviour to use or not an available decision tools, should be a part of DSSs in order to understand constraints and obstacles of farmers while implementing such tools;
- There is a marked communication and knowledge exchange gap between research and field application (growers). This is a severe obstacle for a successful application of innovative approaches in agriculture;

- A number of major crops suffer from the lack of PPPs to control minor pests and there is a need to investigate sustainable strategies to address minor use issues on major crops.

Priority actions:	
Short to medium term	- Move from intensive monoculture to polyculture cropping systems (crop rotation, intercropping, cultivar mixtures etc) - Improve the sensitivity of currently available detection and identification methods to ensure pathogen-free propagation materials - Create EU-wide harmonized monitoring and forecasting systems at field and landscape levels - Further advance and uptake decision support systems (action and damage thresholds and the accuracy to regional/climatic conditions) - Strengthen breeding for resistance, in terms of cooperation/result sharing of pre-breeding results (i.e. on-field validation) - Advance biological control and bio-pesticides - Engage in research in weed management (robotics/sensor technologies, precision farming, stock taking of organic farming research)
Long term	- Develop and adopt robust and resilient cropping systems that allow to achieve emission- and residue-free agricultural production thereby reducing dependence on chemical-based pest management - Engage in prevention as main IPM resource tool and core of resilient systems - Foster the combination of all available means to be included into projects - Put in place an effective and sustainable package of products (biological and chemical) and microbial agents with minimal environmental impact - Develop and adopt smart and innovative technologies in agriculture

Core theme B: Alternative and innovative control

Background:

A growing need for alternatives to chemical compounds have led to development of several mechanical, biological or physical tools which are implemented in pest control. The lack of or insufficient availability of chemical control has taught growers and crop protection specialists that there are alternatives/options to chemicals that can be effective in pest control. The integration of these practices has led to markedly reduced reliance on the use of pesticides in minor crops grown in the protected environment. However, chemical tactics still play an important role in IPM. For this reason, there is a need to complement chemical solutions with non-chemical ones rather than substitute the former with the latter. Only in this way, an effect pest management can be ensured. An example is fruit trees in orchards where a range of non-chemical tools have been combined and used with chemical ones to control pests.

The use of bio-control agents in effective pest control has been reported from several parts of the world. However, the effectiveness of bio-control agents, especially those of fungal isolates, often depends on the climatic conditions (Smith et al 2006) which represent a severe constraint for bio-control. For this reason, any development of new innovative and biological control tools should also include the development of new strategies for optimised application of both old and innovative bio-control agents. In several cases, existing bio-control agents that currently show low or inconsistent activity only need to be used in different ways (eg, different timing or targeted pathogen stage) or in combination to have a better performance. To improve the effectiveness of bio-control agents, the development of weather-driven models both for bio-control agents and for the tritrophic interactions (plant – pathogen – bio-control agent) may result very useful to support decision making about the optimal use of bio-control agents. Likewise, the combination of biological control methods with cultural and physical control methods is essential to have a better performance rather than using bio-control as “a stand-alone pest control measure”.

The use of bio-pesticides is expected to lead to decreased levels of pesticide residues in foods consequently resulting in lower risk for the consumer. However, the approval and the registration of bio-pesticides have been facing several problems due to the application of the same registration criteria to all bio-pesticides, which is impossible given that they are diverse (Czaja et al 2014). In addition to bio-pesticides, elicitors, multiple plant defence primers semio-chemicals, repellents etc. represent interesting alternatives to synthetic pesticides.

Precision agriculture, based on innovative technologies, is a promising approach to optimize crop yield and to reduce the impact of pesticide use. In particular, methodologies applied for the site-specific application of pesticides and traceability of plant tissues affected by biotic stresses have a huge potential to reduce pesticide use, thereby reducing the economical expenses and ecological impacts in agricultural crop production systems (Gebbers and Adamchuk 2010). For example, to optimize the use of pesticide there are several innovative nozzles available and farmers can improve pesticide application efficiency by careful selection of spray nozzles to minimize drift and improve spray retention. As for the detection of early changes in plant physiology, for instance, thermography, reflectance and fluorescence measurements are currently the most promising techniques (Mahlein et al

2012). Detection of early changes in plant physiology by using precision agriculture also enhance important management decisions and help reduce pesticide use in agriculture.

Alternatives to herbicides such as mechanical weed control have proven to be effective on a range of crops depending on soil characteristics and conditions. The development and application of robotic weed control is likely give a boost to the reduction of pesticides in agriculture, although a few complete robotic weed control systems have demonstrated the potential of the technology in the field (Slaughter et al 2008). In addition, drone monitoring of accurate pesticide use represent an innovative tool to reduce the use of pesticide in agriculture.

Increasing reports of pest resistance development to pesticides have been a serious matter of concern in the last decade. To date, many cases of resistance have been reported among all pest categories. This issue is particularly acute for weed management because very few new herbicidal modes of action remain available, further increasing the likelihood of over-reliance on a narrow spectrum of molecules. Historically, resistance of insect pests to insecticides was a major initial driver for the development of IPM (Stern et al. 1959) and for this reason a higher implementation of IPM tactics in the coming years would be desirable to reduce such problems. In particular, there needs a focus to prevent or at least slow the accumulation of resistant lines of pest populations in order to preserve the effectiveness of available pesticides in the short term while alternative control measures to pesticides need to be developed in the long term. However, the reduction of selection pressure for resistance while providing the necessary level of pest control using pesticides remains a challenge. To overcome this problem, the use of pesticides need to be kept at minimum level only when it results absolutely necessary fostering the use of alternative pest management techniques whenever possible. IPM therefore constitutes a fundamental approach to resistance management by minimising the selection pressure.

Assessment of this core theme through the survey highlighted the following research needs:

- While in some countries of Northern Europe mechanical weed control is increasingly practiced, the application in other countries is still limited. Potentially scrutinizing the regional soil and climatic condition and exhaustive exchange and adaptation of potential solutions might tailor such approaches also for other regions;
- Biological control methods have been successfully developed and applied in several greenhouse productions throughout many MS. The application of biological control tools is more limited in fruit orchards and rare on arable crops. There is a need to identify the bottlenecks in the application of biological control in systems where intensive PPP use is still the basis of the protection;

- In development of new innovative and biological control tools co-operation between organic farming and IPM would be desirable to enhance a more systemic understanding. Engagement of industry and farmers is a basis for the development of alternative and innovative control measures;

- The available knowledge on the potential of natural enemies on pests at field level should be tested within different contexts. There is a need to evaluate how different cropping systems influence the population dynamics of natural enemies at landscape level. Likewise, improved knowledge of relationships between phytophagous, pathogens and weeds and their natural enemies and/or antagonists (multi-trophic relationships) are needed;
- A number of major crops suffer from the lack of PPPs to control minor pests and there is a need to develop alternative strategies to pesticides to address minor use issues on major crops;
- The transfer of scientific knowledge into practice - taking into account new approaches such as the development of bio-pesticides or biological pest control – need to be promoted;
- Monitoring of the resistance occurrence to guide decision making in order to develop sustainable pest resistance management strategies in order to slow down or prevent the development of resistance within the targeted pests;
- Identification and assessment of parameters that reduce or enhance multi-trophic relationships and their consideration for integrated control programs are needed.

Priority actions:	
Short to medium term	- Prioritize biological, biotechnical, physical controls and mechanical weed control - Create and improve networking for detection, monitoring, mapping and regular updating of the resistance development
Long term	- Develop precision sensing and spraying for optimized use of pesticides - Evaluate the possible use of nanotechnologies in plant protection - Develop tools and methods for resistance detection of pests

Core theme C: IPM in minor Crops

Background:

Whilst many major crops, such as cereals and maize, benefit from the access to a variety of pesticides (Kuck and Gisi, 2006), a wide range of crops (commonly known as minor crops) grown in Europe suffers from a lack of PPPs (Lamichhane et al 2015). In particular, vegetables, fruits, nursery stock and ornamentals are high-value crops representing more than 20% of the value of EU's total agricultural production. Sustainable production of such crops is vital for both human health and European economies. For these crops the availability of crop protection solutions has been rapidly decreasing in Europe. This is mainly due to the introduction of new crops and pest species into Europe and the lack of PPP. The direct economic impact due to the absence of viable plant protection solutions for minor crops has been estimated over a billion Euros per year, impacting 9 million hectares throughout Europe. IPM can serve as the basis to develop long-term solutions to reduce the reliance on pesticides also within the context of minor uses.

In order to overcome the increasing scarcity of potentially available MU solutions, several initiatives within the EU are ongoing. Examples are the EU Technical Working Group on MU, several Commodity Expert Groups and the recently set up MU Coordination Facility co-funded by the EC (Lamichhane et al 2015). The current EU Minor Use Database (EUMUDA; http://www.eumuda.eu/Apps/WebObjects/PSInfoEU.woa), already provides a basis to enable and improve the cooperation between the EU Member States in the field of MU. . The list of common observed minor use problems which need to be solved by IPM methods, a result of workpackage 3 of the ERANET C-IPM, is made available to the stakeholders through the EUMUDA database. Some of the ongoing initiatives in this respect, refers to the creation of a common list with common observed problems for MU. This database will also relate to the work on the other priority actions in the short term.

Hence, there is a need of an interplay between the ongoing MU activities at European level and the ERA-Net C-IPM. For example, there are ongoing EU projects on *Drosophila suzukii*, such as Dropsa (https://secure.fera.defra.gov.uk/dropsa/) and another project (DROSKII) in the frame of the ERA-Net Euphresco II, which need to be taken into account for any possible thematic complementarities. Likewise, many non-European countries, such as the USA and Canada, have IPM programs for minor crops and some of them have a strong collaboration with European programs. For this reason, a link with non-European countries on MU issues is essential, in particular with the North American IR4 and global MU summit programs.

Mapping and analysis of minor uses problems and possible IPM solutions have been performed within this ERA-Net which resulted in the preparation of an inventory. The latter aimed to establish a table of needs for IPM solutions for minor uses in Europe. The inventory made is part of the ERA-Net C-IPM and is complementary to the work already done by the existing EU minor use groups (the latter is not part of the ERA-Net). Further elaboration of the core topics by ERA-Net C-IPM partners will result in calls for future research.

As for potential solutions to help solve MU problems, in addition to the need of PPPs, there is a need for breeding programs for minor crops as breeding for resistance represents a potential tool for pest management also in minor crops. However, breeding for resistance is too cost intensive and lengthy and as such cannot be considered as an effective approach to solve MU issues in the short term. For this reason, all other control measures need to be prioritised.

Priority actions:	
Short to medium term	- Put in place an European network to harmonise all ongoing activities related to minor uses - Create an European inventory of minor use problems and available solutions and rank them in order of importance in collaboration with EUMUDA - Encourage knowledge sharing with stakeholders on a selected number of topics - Develop alternative solutions based on inventory and interests of (international) stakeholders - Promote the development of alternative solutions to chemicals and their application - Liaise with non-European programs on minor uses in order to share knowledge and solution finding
Long term	- Foster activities and initiatives related to breeding for resistance for minor crops

Core theme D: Pesticide impact & IPM implementation indicators

Background:

Agriculture of the last five decades in general and crop protection in particular have markedly benefitted from the availability of a number of pesticides. These benefits include increased crop and livestock yields, improved food safety, human health, quality of life and longevity, and reduced drudgery, energy use and environmental degradation (Cooper and Dobson, 2007). On the other hand, several overuses of pesticides have led to numerous problems related to human health and the environment.

Serious concerns have been raised over the last years about health risks resulting from direct pesticide exposure and from residues in food and drinking water. Direct exposure to pesticides often occurs in the case of agricultural workers in open fields and greenhouses, workers in the pesticide industry, and exterminators of house pests (Damalas et al 2011). The consumption of food with pesticide residues and contaminated drinking water is another means of exposure. The adverse effects on the environment in *sensu lato* depend on the toxicity and the physic-chemical properties of the pesticide (persistence, bioaccumulation, mobility, leaching, etc.) and the conditions of application (doses, techniques, risk mitigation measures, soil or substrate properties, climatic conditions, etc.).

Risk assessment of the impact of pesticides on human health and/or on the environment is a complex task because of differences in the periods and levels of exposure, the types of pesticides used (regarding toxicity and persistence), the agro-environmental characteristics of the cropping areas where pesticides are usually applied. Moreover, the number of the scenarios and criteria used and the method of their implementation to evaluate the adverse effects of pesticides on human health and the environment could affect risk assessment. It must be stressed that information provided by the industry and the assessments for registration only consider single product's applications while the consumers and the environment are exposed to a set of different products, with possible cocktails effects.

As long as pesticides are widely used across Europe, there need strategic research activities to systematically investigate the efficacy of different pesticide products against different pests under different pedo-climatic conditions. In many cases, several works have already been conducted in this regard and there exist efficacy data produced and supported by agrochemical companies. Cooperation between the EU initiatives and those private one would be highly beneficial to make use of already existing data based on which specific further needs for additional research may be identified.

Likewise, indicators exist to evaluate the farm financial performance, pesticide use at farm and regional or national level, resistance development and eco-toxicological levels which need to be recovered and used. However indicators to assess the uptake of IPM on a regional or national scale are still lacking as well as indicators which assess and compare the risks of different pesticide application schemes.

The social aspects and knowledge brokering to enhance the adoption of more systemic understanding of sustainable crop production are essential. To this aim, pedagogic science might offer insights on how the message is best disseminated thereby causing permanent change in practices. Socio-economic performances that facilitate IPM implementation need to be directed not only to producers but to the entire value chain. Research on IPM should therefore be designed from a multi-actor perspective, and address not only availability of approaches and tools, but also socio-economic factors determining their acceptance. Apparently, there is a mismatch between sustainability of crop protection strategies as perceived by consumers (NGOs and retailers), farmers, and scientists. This calls for a better insight into the impact of strategies on different sustainability indicators, as well as the mitigating effect of measures such as MRLs on these impacts.

Co-innovation is a novel and innovative paradigm which consists in the integration of new ideas and approaches, from several internal and external sources, to a platform that aims to generate new organizational and shared values (Lee et al 2012). Such an innovative approach proposed and adopted should contribute in creating shared value for all stakeholders. More specifically to IPM, co-innovation is imperative in reaching the agricultural community and having a better impact on IPM implementation.

Assessment of this core theme through survey highlighted the following research needs:

- The further development of specific crop scenarios are needed for the assessment of the use of pesticides, considering the specific agro-climatological conditions and especially crop management ;
- Networking for the detection of and monitoring the development of resistance to pesticides in pest populations. Risk assessment of development of pest resistance to pesticides and development of integrated approach to prevent or mitigate such resistance in pest populations;
- The development of indicators to assess pesticide impact need to be simple to communicate and to use. Rather than single indicators, a set of indicators are useful so that they can be used at farm, regional and national levels.
- In addition to develop quantitative indicators for implementation of IPM principles and to assess consumer and environmental protection measures, qualitative research is also needed on how the process is perceived and what are the success stories or obstacles of adopting new practices in plant protection.

- Development of appropriate and well-maintained spraying equipment and the optimization of those already existing ones to minimise human exposure to pesticides and their potential adverse effects on the environment;

- Research on the evaluation of socio-economic performance that facilitate IPM implementation is needed

Priority actions:	
Short to medium term	- Foster awareness raising programs due to the use of pesticides and encourage for the adoption of non-chemical tools - Assess if pesticides are used also when other non-chemical solutions are available
Long term	- Develop indicators to assess the implementation of the general principles of IPM - Develop indicators to assess consumer and environmental protection in *sensu lato*

Collaboration with other ERA-NETs

A number of additional topics have been identified through the mapping as well as through discussion with C-IPM partners and stakeholders. It has been agreed that these topics are pertinent to IPM, but that because of time and resource limits C-IPM cannot deal directly with them. Consequently, it is essential that C-IPM collaborates with other ERA-NETs within which several activities related to these topics are ongoing. This is important to avoid any overlapping of activities as well as for the rationalisation of funding. Figure 4 reports on such sub-topics and their links with other ERA-NETs.

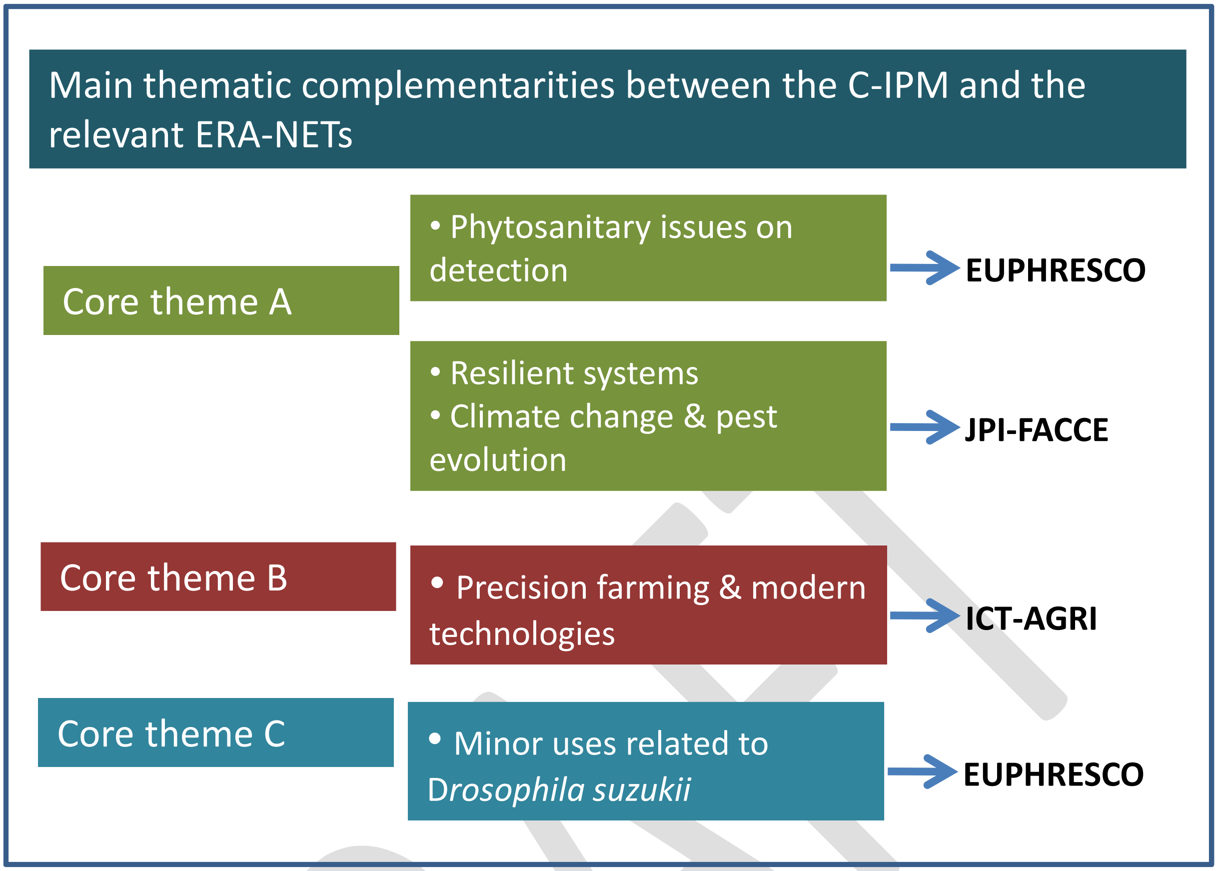

Figure 4. Main thematic complementarities between the C-IPM and other ERA-NETs

International collaborations

IPM covers a broad range of topics which markedly increase the possibility of collaboration with ongoing initiatives at international level. This is an important advantage for the ERA-Net C-IPM to position itself not only at European but at global level. To this aim, C-IPM is open for any kind of international collaboration that help identify opportunities and mechanisms for knowledge transfer/sharing; training & dissemination of information of IPM related research. For example, issues related to monitoring, detection and control of invasive pests, obstacles related to IPM implementation, minor uses and speciality crops are some of the potential topics for which the ERA-Net C-IPM may foster collaboration with other international projects.

Calls for transnational research projects

In order to facilitate joint transnational calls within the framework of the ERA-Net C-IPM, questionnaires were sent out to potential partners who could provide funding. Three calls are foreseen within the ERA-Net C-IPM: one pilot call in 2014 to be funded in 2015, one main call in 2015 to be funded in 2016 and the second main call in 2016 to be funded in 2017. Most partners agreed to fund the 2015 call and the 2016 call and some of them showed willingness to fund a 2015 pilot call.

The implementation of the calls will be done through: i) decision on the time line of the implementation, ii) proposal submission, peer review process, funding decision, and iii) funding organisations supporting the call.

At least two calls will be launched within the C-IPM which will help foster further research collaboration among the European researchers. In addition to the calls on topics of common interests, sharing results, coordination of European research, dissemination of the research based on the DSS, meta-analysis and networking of demo farms will be the activities promoted by this ERA-Net.

Concerning the calls, it is agreed to contribute to common "coordination costs" via a virtual common pot. Each funding organisation will fund research groups from its country depending on its own national rules. There will be a two-step competitive call procedure.

Overall, the two-step process requires at first the submission of short pre-proposals describing the research idea. From these a short list will be selected and the respective consortia will be invited to submit full proposals. Both pre- and full proposals need to be submitted electronically by the applicant (consortium coordinator). A proposal template and guidelines will be provided by the Joint Call Secretariat in order to support the applicants in terms of the proposal format. The Joint Call Secretariat will be hosted by INIA, Spain.

Delivery of the strategic research agenda

Communication and dissemination

Communication is a key to awareness raising concerning the challenges that IPM has been facing. This is also an effective tool, mainly in the era of "high-tech" to convey any important message to the actors concerned.

The ERA-Net C-IPM intends to foster communication between all the players who directly or indirectly can contribute to the objectives of this network. They include the scientific community, policy makers, stakeholders and/or growers and funders. Most of the communication activities are performed through the website: http://c-ipm.org.

In addition to the website, a large number of stakeholders identified previously are informed via electronic newsletters on a regular basis. More specifically, progress achieved within the different work packages and the crucial decisions made by the executive committee are conveyed to all interested players related to the C-IPM activities. The main aim of doing so, is to receive feedback from all relevant stakeholders on the critical research needs.

Conclusions

The ERA-Net C-IPM aims to foster IPM implementation in Europe in the short term, while for the long term, initiatives are designed to shape the future European Research Area. This will be done by pooling national resources and avoiding fragmentation and overlapping of any research effort related to IPM. The ERA-Net C-IPM will play a crucial role also in providing the research base by feeding European policies on IPM issues of relevant importance, both in the short and long term. By working together at European scale, the ERA-Net C-IPM is expected to foster the exchange of existing tools and infrastructures as well as develop new ones.

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Annex 1: An overview of long list topics identified by the C-IPM partners for the calls 2015 and 2016

Cluster	Topics	Sub-topics
Preventive and sustainable (pest) management (A)	Breeding and implementation of resistant/tolerant cultivars (A1)	Breeding for resistance against pests
		Phenotyping improvement to help resistance
		Methods for certifying seeds/propagation materials being healthy
		Improved methods of sceening phenotypes
		Mapping of resistance activities
		Prevention methods for seeds/propagation materials being infected during production
		Strategies to introduce sustainable resistance (R-gene stacking, S-genes etc.)
		Methods to certify culture substrate for absence of pests and presence of buffering microrganisms
		Buffering microrganisms/endophytes added to seeds and/or propagation materials
	Integrated, sustainable and resilient cropping system (A2)	Crop rotation, Intercropping, cover crops
		Companion planting + trap crops + under sowing + variety mixtures
		Tillage, prevention of soil degradation, resilient soils
		Protection of surface water, reduction of Nitrogern leaching
		Development of protected production other than greenhouse
		Resilient systems (e.g. soilless, biological/physical barriers for pests), emission barriers, etc.
	Innovative and new pest monitoring tools and Decision Support Systems (A3)	EU-wide harmonized monitoring and forecasting systems at field and landscape levels
		Development, improvement and validation of models and tools for various crops X pests combinations
		generating life cycle data and improved sampling methods of pests/weeds
		Implementation and integration of monitoring and DSS into Integrated Cropping Systems
		Harmonization, standardization & validation of forcasting models (e.g. IT systems with unique software platform, covering regions/cross border, different meteorological data format)
		Improvement/redefinition of economic threshold values
		Monitoring of virulence and population dynamics, damage thresholds for applicable DSS
		Forecasting systems scaling and sensors
		Sampling methods for accurate monitoring, innovative detection and identification methods
		Strategies for durable resistance management (preventing R-breaking), resistance breeding for competition with weeds

Cluster	Topics	Sub-topics
Alternative and innovative control (B)	Diversification of direct control methods according to IPM toolbox (B1)	Biological control of pests
		Natural agrochemicals (medicinal or aromatic plants, resistance inducers, bio-pesticides)
		Biotechnical (traps, semiochemicals) and physical control (e.g. different types of barriers)
		Mechanical control (e.g. weed control)
		Habitats for biological control (e.g. field margins encouraging natural enemies)
	Pests resistance management (B2)	Development of tools and methods for resistance detection of pests
		Networking for detection, monitoring, mapping and regular updating of the resistance development
		Advising network to manage resistances of pests in specific crops (regional or transnational)
		Widely shared European network of information on resistant population of harmful organisms
	Application techniques of plant protection product (B3)	Drift reducing application, precision agriculture (precision sensing and spraying)
		Modern technologies for weed control (e.g. robotics)
		Evaluation of nanotechnologies in plant protection
		Alternative methods to spraying (e.g. seed treatments, phytodrip, drenches etc.)

Cluster	Topics	Sub-topics
IPM in Minor Crops (C)	Weeds in vegetable crops (C1)	Whole cropping system should be considered (crop rotation, way of harvesting, biocontrol methods).
		Baby leaves, herbs, some cereals and rice are also included
		Biological control methods (microbials).
	Flies in vegetables (C2)	Delia and Psila spp. in Brassica crops, other root & tuber crops (carrots and celery) and bulb vegetables (onion and garlic)
		Resistance breeding and repellants
		Research available in UK, FR, DK, DE and NL
		Focus group IPM methods in Brassicas
	Aphids in leafy vegetable (C3)	Research results available although it is still considered as problem
		Collaborate with existing activities and exploit available results
	Fruitflies in stone fruits, pome fruits, berries and small fruit (C4)	*Drosophila suzukii* and other fruitflies
		Existing research with Dropsa and Dropskii projects
		Matching with ongoing research and private companies
	Mites (spider, rusts and bud) in Berries and Small fruits (C5)	Existing research programmes in BE on strawberries
	Insects (Leaf eating beetles and spidermites) in Hop (C6)	Existing research: DE, BE: Flanders and NL (e.g. attractants for beetles)
	Whiteflies and Thrips in ornamentals/vegetable (C7)	Adaptation of existing research results, knowledge sharing
		Biocontrol of vectors
	Soil borne pests and diseases (often polyphagous) (C8)	Diseases on vegetable crops (Brassica); sweet corn (clubroot, Sclerotinia, Fusarium, Verticillium)
		Insect pests on vegetable crops (Brassica); sweet corn
		Existing programme: BE (Flanders), focus group IPM on suppression of soil borne diseases in vegetables
	Leaf spots and Downy mildew in leafy vegetables (C9)	Resistance breeding against Downy mildew, Fusarium, Podosphaera fusca, *Meloidogyne* spp., *Ralstonia so*
	Pests/diseases in legume crops (C10)	Peas and beans in particular
	Diseases in stone fruits (C11)	Both bacterial, fungal and viral

Cluster	Topics	Sub-topics
Pesticide impact & IPM implementation on indicators (D)	Use of existing risk indicators to evaluate pesticide use and impact (D1)	Indicators to assess the implementation of the general principles of IPM
		Indicators to assess consumer protection, environmental protection in sensu lato (in combination with DSS)
	Development of IPM implementation indicator	Performance and uptake of IPM

Annex 2: Abbreviations and definitions

C-IPM	Coordinated Integrated Pest Management
CWG	Collaborative Working Group
DSS:	Decision Support System
ERA-Net	European Research Area Network
IPM:	Integrated Pest Management
JTR	Joint Trans-national Research
MRL	Maximum Residue Levels
MS	Member States
MU	Minor uses
NAP	National Action Plan
NGO	Non-governmental Organization
Pests	Collectively refers to animal pests, weeds and plant pathogens
PMS	Pest Monitoring Systems
PPP	Plant Protection Products
R & D	Research and development
SCAR	Standing Committee of Agricultural Research
SRA	Strategic Research Agenda