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Nordic Association of Agricultural Scientists

NJF Seminar 484

Biodiversity Based Integrated Pest Management in Field Crops

3rd September 2015, Wiiks Castle, Uppsala, Sweden

NJF

NJF Seminar 484

Biodiversity Based Integrated Pest Management in Field Crops
3rd September 2015
Wiiks Castle, Uppsala, Sweden

Organizing committee

- Associate professor Velemir Ninkovic, Swedish University of Agricultural Sciences, Sweden
- Dr Björn Andersson, Swedish University of Agricultural Sciences, Uppsala, Sweden
- Senior scientist Irmeli Markula, NJF section Plants, Finland
- Professor Inara Turka, Lativa University of Agriculture, Latvia

Seminar secretary

Roland Sigvald, SLU and NJF (roland.sigvald@slu.se or njf@njf.nu

NJF seminar 484 and NOVA PhD course

"Biodiversity Based Integrated Pest Management in Field Crops"

Location: Wiiks castle, Uppsala
Time: 3rd September 2015
Target group: PhD students, advisors, researchers, farmers

Program

09.00-10.00	**Registration**
10.00-10.30	**IPM in Europe** Professor Per Kudsk, Aarhus university, Department of Agroecology, Slagelse,
10.30-11.00	**Implementation of IPM- example from Sweden** Plant protection specialist, advisor Göran Gustafsson, Swedish Board of Agriculture, Sweden
11.00-11.30	**The role of IPM in plant disease control** Dr Björn Andersson, Swedish University of Agricultural Sciences, Department of Forest Mycology and Plant Pathology, Uppsala, Sweden
11.30-12.00	**The first steps of Integrated Plant Management in Latvia** Professor Inara Turka, Latvia University of Agriculture, Latvia
12.00-13.00	Lunch
13.00-13.20	**The Change in CAP for Finland for Berry and Fruit Growers and its Implications for Field Crops** Professor Ingeborg Menzler-Hokkanen, Department of Agricultural Sciences, University of Helsinki, Finland
13.20-13.40	**Enhanced biodiversity for oilseed rape crop protection**, Professor Heikki M.T. Hokkanen, University of Helsinki, Finland
13.40-14.00	**Inspecting the ecological mechanisms operating in spring turnip rape (*Brassica rapa* ssp. *oleifera*) intercropping** Senior Research Scientist Sari J. Himanen Natural Resources Institute Finland (Luke), Finland
14.00-14.20	**Forecasting pests and diseases of field crops-an important tool in IPM** Associate professor Roland Sigvald, department of Ecology, SLU, Uppsala, Sweden

14.20-14.40 **Observations of Biodiversity in different crop management systems on farms in Sörmland**, Anna Linnell, Crop Advisor, Hushållningssällskapet, Sörmland

14.40-15.00 Coffee

15.00-17.30 **Presentations by PhD students**

- **Weed suppression by winter cereals: Relative contribution of competition for resources and Allelopathy,** Antje Reiss, PhD student at Aarhus University, Denmark
- **Weed seed germination in winter cereals under contrasting tillage systems,** Ananda Scherner, Department of Agroecology, Aarhus University. Forsøgsvej 1, Slagelse – 4200, Denmark**.**
- **Integrated pest management of two of the most important pests in Swedish greenhouse cucumber production**
  Mira Rur, Plant Protection Biology, Swedish University of Agricultural Sciences, Alnarp, Sweden
- **Ensuring a sustainable supply of clover seeds – dealing with poor seed set and seed predation,** Veronica Hederström, Department of Plant Protection Biology, Swedish University of Agricultural Sciences, Alnarp, Sweden
- **Sweet potato virus detection, characterization, elimination and management in Ethiopia**, Dereje Haile, Dep of Plant Sci., Norwegian University of Life Sciences (NMBU, Ås, Norway
- **Development of IPM tools for the control of aphids and cereal leaf beetles in grain cultivation,** Elias Van De Vijver
- **The Heterogenity of Landscape Enhances Species Richness of Ground Beetles (Coleoptera: Carabidae) in Wheat Fields**, Jānis Gailis, Institute of Soil and Plant Sciences, Latvia University of Agriculture, Latvia
- **Variety mixtures –Linking interactions between plants and insect pest control**, Iris Dahlin, Swedish University of Agricultural Sciences, Department of Crop Production Ecology, Uppsala, Sweden
- **Enhanced biological control through non-crop vegetation and semiochemical in Swedish apple orchards,** Joakim Pålsson, Dept. of Plant Protection Biology, Integrated Plant Protection Unit, SLU, Alnarp
- **Biannual monitoring of pyrethroid and neonicotinoid susceptibility in Danish pollen beetle (Meligethes aeneus F.) populations**, Caroline Kaiser, Aarhus University, Department of Agroecology, Flakkebjerg Research Center, Denmark

- **Flowery strips do not enhance predation rate measured by artificial caterpillars in winter wheat (*Triticum aestivum*) fields in Denmark**, Marco Ferrante, Aarhus University, Department of Agroecology, Flakkebjerg Research Centre, Slagelse, Denmark

- **Impacts of fallow strips on biological control of cereal aphids**, Marjaana Toivonen, Department of Agricultural Sciences, University of Helsinki, Finland

- **Can nutrients strengthen plant - predator interactions in agro ecosystems?,** Laura Riggi, Department of Ecology, Swedish University of Agricultural Sciences, Uppsala, Sweden

- **Fungicide resistance analysis of Zymoseptoira tritici populations in the Northern Zone**, Thies Marten Wieczorek, Department of Crop Health, Aarhus University, Denmark

- **Remote plant virus detection**, Tobias Urban Teodor Lindblom, Swedish University of Agriculture Sciences, UPPSALA, Sweden

- **Characterization of soil-borne plant pathogens using next generation sequencing**, Rumakanta Sapkota and Mogens Nicolaisen, Aarhus University, Faculty of Science and Technology, Department of Agroecology, Slagelse, Denmark

- **Characterization of nematode pests of Enset (*Ensete ventricosum* Welw. Cheesman) and their management,** S. Kidane, International Institute of Tropical Agriculture, Nairobi, Kenya

- **Effects of integrated pest management (IPM) on the population dynamics of the perennial weed species *Cirsium arvense***
  Varwi Jacob Tavaziva, Swedish University of Agricultural Sciences (SLU) Department of Crop Production Ecology, UPPSALA, Sweden

- **Title: Social Acceptability of Climate Friendly Sustainable Intensification Actions in Plant Production**
  Jaana Sorvali, Department of Agricultural Sciences, University of Helsinki, P.O. Box 27(Latokartanonkaari 5), FI-00014 University of Helsinki, Finland

17.30-18.30 Discussion and poster presentation

19.00 Dinner

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IPM implementation and research in Europe

Per Kudsk, Aarhus University, Flakkebjerg, DK-4200 Slagelse, Denmark

The IPM concept has developed significantly since the introduction of "integrated control" defined as "applied pest control which integrates biological and chemical control" (Stern et al. 1959). The concept was initially developed by entomologists but IPM now applies to all pests. IPM was taken up by the EU in the EU Framework Directive 2009/128/EC on the sustainable use of pesticides adopting almost the same definition of IPM as FAO. Directive 2009/128/EC requires that all EU Member States develop a National Action Plan which also ensures that IPM was implemented by all professional users of pesticides January 1, 2014.

In many EU countries confusion still reigns when it comes to defining what IPM is and how it distinguish itself from what is considered good agricultural practice. This is one of the reasons why the EU has supported major research initiatives to support the implementation of IPM in member states. In this presentation the projects ENDURE and PURE will be presented.

ENDURE was a so-called Network of Excellence that focused more on consolidating existing knowledge and disseminating the information to end-users in the form as training material and information databases rather than initiating new research activities although some research activities were launched. On the ENDURE website (www.endure-network.eu) users can find publications ranging peer-reviewed papers and leaflets to IPM training guides. ENDURE finished in 2010 but the network still exists and maintains the website which nowadays is regarded as a primary source of information on IPM. Examples of the output of ENDURE are presented.

In contrast to ENDURE, PURE was a research project aimed at generating knowledge and new innovative solutions. PURE was initiated in 2011 and ran until March this year (www.pure-ipm.eu). PURE consisted of 6 work packages dedicated to find novel IPM solutions in winter wheat and maize based rotations, field vegetables, pomefruit, grapevine and protected vegetables and 4 work packages devoted to generated new knowledge and technologies for IPM. A unique feature of PURE was that it adapted a Design-Assessment-Adjustment cycle, i.e. the IPM solutions tested in year 1 was assessed and adjusted, if required, in the subsequent year. The assessments were made with DEXiPM, a multi-criteria assessment tool developed in ENDURE. During the presentations key outputs of PURE will be presented.

The EU Commission continues to support IPM research activities now as part of the Horizon 2020 programme. The previous call had several topics related to IPM and so has the forthcoming call. An interesting change is that the EU now requires that the applicant adopt a so-called 'multi-actor approach'. This means that the applicant should involve the end-users from day one, i.e. when the concept of the project is being developed to ensure that the outcome of the project is taken up by the end-users.

Implementation of IPM – examples from Sweden

Göran Gustafsson
Swedish Board of Agriculture
Regional Plant Protection Centre, Linköping

Integrated Pest Management (IPM) is nothing new. The concept was established in the late 1950s as a result of beginning resistance to some pesticides. The interest for finding other solutions besides chemicals started.

IPM can be summarized in:
1) Prevention
2) Knowledge about field situation
3) Necessary treatment, not routine
4) Following-up

All professional growers in EU must use IPM from January 1, 2014. It will not be any dramatic change. Many farmers already use IPM in some ways. A good crop rotation, use of healthy and clean seeds, resistant varieties, use of thresholds and DSS, treatments when it is needed and not as a routine, are some examples.

Different kinds of information are important tools for implementation of IPM and have high priority in Sweden.

Examples of such information developed in Sweden are:
Strategies for Chemical Treatment, a booklet with facts about pesticides and how to use them
Cultivation Recommendations, brochures for 10 different crops
Diagnosis books for pest, diseases and weeds
Diagnosis in mobile
Diagnosis quiz
Weekly reports, field situation based on the work with forecasting and warning
Plant protection messages, urgent warnings and recommendations about pests and diseases

The role of IPM in plant disease control

Dr Björn Andersson
Swedish University of Agricultural Sciences
Department of Forest Mycology and Plant Pathology, Uppsala, Sweden

Control of plant diseases in agricultural crops is to a large extent based on the use of fungicides today. In the short time perspective (usually a single crop), fungicides can be applied prophylactically or curatively to control situations were a plant pathogen threatens the crop. This practice has given farmers the possibility to attain high levels of control of many serious and important plant diseases, resulting in increased and more stable yield levels, both quantitatively and qualitatively.

However, the environmental impact and other unwanted effects of fungicide are subject to discussion. Also, dependency on fungicides has caused problems with development of fungicide resistance in many plant pathogens, depleting the arsenal of substances available to control plant pathogens.

A move from direct **control** to more long term **management** is needed when implementing integrated approaches to handle plant disease problems. We must shift from **curing** plant diseases towards **preventing** plant pathogens to infect our crops. To achieve this, an adoption of a more holistic view on plant disease problems and an implementation of a system approach to crop protection are necessary among farmers and advisors. Fungicides will continue to play a role also in future agriculture, but not by taking the role of more complex crop protection approaches based on agronomic, physical and biological principles.

The first steps of Integrated Pest Management in Latvia

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The first experience with implementation of IPM in Latvia we have had from year 2009. Part of orchard, berries and starch potato growers, totally about 400 farmers, are registered as integrated growers. They can follow the all requirements and they are satisfied about results of integrated growing and plant protection system.
Adaption of IPM for field crops will be more complicate. The main field crops in Latvia are all grain crops: winter and spring wheat, rye, oats and spring barley; winter and spring oil seed rape, legume crops (mainly field beans). Each farm depending of region grows at least three of these crops or more on several fields. Monitoring of pests and diseases on a farm level for each specific field could be the main difficulty. The execution of monitoring requirements in a single specific field consumes time and resources, and it demands extra costs. To help farmers, Latvian State Plant Protection Service offered lot of free information in their home page: EU requirements, recommendations, warnings about pests and diseases in different regions on a certain growing stage of crop, visual aids and descriptions of different crop pests and diseases. In spite of that, farmers do not want to carry out monitoring themselves alone without expert assistance. Therefore two year transition period has been given to farmers to get more knowledge and help from researchers and experts, something which will challenge and encourage to make quality IPM.

The Change in CAP for Finland for Berry and Fruit Growers and its Implications for Field Crops

Ingeborg Menzler-Hokkanen1, Heikki M.T. Hokkanen1 & Marja-Leena Lahdenperä
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The new support scheme for Finnish fruit and berry growers is explained by Reskola, V-P. (2015), Ympäristökorvaus käynnistymässä (Puutarha & Kauppa Nr. 3/2015, p. 14). In Finland, new CAP measures dealing with environmental subsidies to agriculture, propose to change the statutes and to include specifically entomovectoring. Conventional growers, who replace chemical fungicide sprays by entomovectoring of microbial products on their berry and fruit crops for a minimum of 5 years, will receive 500 €/ha/year in environmental support. It is expected that the new subsidy scheme will encourage berry and fruit growers to take up the alternative method. The model which Finnish legislation is providing might help other countries also to adopt a similar scheme. What is at stake in Finland are the consequences of unguided introduction of the new technology. There is no infrastructure to support the introduction and uptake of the entomovectoring technology. In case growers run into problems, no infrastructure is available to provide knowledge and know-how for the introduction of the new technology. If the technology fails on the fields, it is because of the mode of introduction.

Also the theoretical background need further indepth knowledge. So far targeted precision biocontrol and improved pollination were studied Europe-wide in the EU ERA-NET CORE ORGANIC 2 project BICOPOLL. A case study was conducted aiming at the control of strawberry grey mould Botrytis cinerea, with the biocontrol fungus Gliocladium catenulatum, vectored by honey bees or bumble bees. A joint field trial carried out in five countries targeted strawberry cultivations in open field, and ideally included four treatments: untreated control, chemical fungicide, entomovectored biocontrol, and chemical and biocontrol combined. In organic fields, no pesticide treatments were included. The proportion of mouldy berries, and/or the marketable yield of healthy berries were recorded from each treatment, along with other parameters of local interest. A pilot study was started in Finland in 2006. In 2012 field trials were started in Estonia and in Italy, while in Finland already large areas > commercially used entomovectoring. In 2013 the experiments were expanded to Slovenia and Turkey, and were continued in 2014. In total, 26 separate field tests were conducted using entomovectoring and Gliocladium catenulatum (Prestop® Mix) on strawberry, and five additional on raspberry. Efficacy results have been excellent throughout the field studies. The results show crop protection equalling or exceeding that provided by a full chemical fungicide program, under all weather conditions and over a wide geographical spread (from Finland to Turkey). Under heavy disease pressure entomovectoring provided on average 47% disease reduction, which is exactly the same as obtained by multiple fungicide sprays.

Under light disease pressure, biocontrol decreased grey mould on average by 66%, which is more than by the fungicide sprays. The concept has proven to be effective on a wide range of crops, such as strawberries, raspberries, pears, apples, blueberries, cherries, and even grapevine. A conservative estimate for Finland is that over 500 ha of strawberry cultivation currently use the technique (≈15% of strawberry growing area). To make full use of the entomovectoring technique, organic berry and fruit growers are recommended to (i) keep bees by themselves, or to hire the service from local beekeepers for entomovectoring; (ii) manage vegetation within and around the target crop to support the activity of bees and other pollinators, which can help to disseminate the beneficial microbes within the crop. Beekeepers are recommended to (i) market pollination and biocontrol services to fruit and berry growers, and (ii) in the management of bees and the dissemination activity to ensure that all operations are reaching full efficacy. Biocontrol product manufacturers are recommended to further develop products and their formulations specifically for entomovectoring, because current formulations - although working in practice - are initially optimized for other uses. Administrators are recommended to register, and to promote the registration of biocontrol products, which are needed for effective control of the target diseases and pests amenable to entomovectoring. In all countries the lack of registered products is a major bottleneck to adopting these techniques more widely.

Entomovectoring as a new technology got strong support by the change in the CAP support sytem for Finnish berry and fruit growers. The potential for applications of entomovectoring for field crops have not been researched yet for the Nordic region.>

Keywords: antagonist, Apis mellifera, apple, biological control, Bombus, Botrytis cinerea, CAP, Clonostachys rosea, dispenser, entomovectoring, environmental subsidies, field crops, fungal diseases, Fusarium avenaceum, Gliocladium catenulatum, integrated control, new CAP measures, Nordic region, organic production, Prestop® Mix, raspberry, strawberry,

Enhanced biodiversity for oilseed rape crop protection,
Professor Heikki M.T. Hokkanen, University of Helsinki, Finland

Inspecting the ecological mechanisms operating in spring turnip rape (*Brassica rapa* ssp. *oleifera*) intercropping

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Intercropping is a means of increasing agroecosystem biodiversity to accomplish multiple benefits for the co-crops via ecological interactions. Such interactions include e.g. provision of biologically fixed nitrogen, suppression of co-crop herbivory via associational resistance, and enhanced building up of natural enemy populations via attractive alternative food sources. I experimented intercropping the oilseed *Brassica rapa* ssp. oleifera, i.e. spring turnip rape, in a 3-year field experiment in central Finland with three different intercrops, each hypothesized to facilitate turnip rape growth and limit its herbivore pressure via one or several ecological interactions and operating mechanisms. The co-crops used were: the strong volatile emitter *Tagetes minuta* L. (Mexican marigold), the extrafloral nectar producing legume *Vicia sativa* L. (common vetch) and under-sown weed-suppressing *Trifolium repens* L. (white clover) legume. I present results on herbivore and natural enemy incidence in the different intercrops and the impacts of intercropping on yield of turnip rape. The results are discussed based on the hypothesized operating mechanisms (associational resistance, natural enemies, increased competition towards weeds) potentiated by intercropping.

Forecasting pests and diseases of field crops- an important tool in IPM

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The economic importance of pests and diseases of agricultural crops, availability of new, highly effective pesticides, and the negative effects of insecticides, fungicides and herbicides have focused attention on methods in crop protection and forecasting pest outbreaks. Effective warning and forecasting systems are important tools to reduce chemical treatments. These systems will require better knowledge of the dynamics of insect population, viruses, and fungal pathogens as well as economic threshold values for the damage they cause to increase profitability and at the same time minimise the negative effects on flora, fauna and ground water.

Aphids are very important on a great number of crops, not only because the direct damage they cause but also indirectly by transmitting virus. Aphicide treatments have been profitable on about 70% of national barley and oat crops in Sweden during years with heavy outbreaks of *Rhopalosiphum padi.* but less than 10% in years with low infestations. The forecasts are based upon aphid population on the winter host (egg on *Prunus padus*) and spring migration using suction traps.

Potato virus Y (PVY) is one of the most important virus diseases on potatoes in Sweden and many other countries in northern Europe. A simulation model has been developed, which predicts the extent to which the proportion of progeny tubers infected with PVY^{O} will increase during late summer. Proportion of virus sources, latent period, mature plant resistance, vector efficiency and cultivar susceptibility are some factors in the model.

The frit fly, *Oscinella frit*, is a stem- boring fly, which causes damage to cereals. A method for forecasting the infestation of frit flies has been developed in Sweden based upon such factors as timing between insect and plant development, population level and the weather during egg-laying period. During spring and early summer the temperature sum is calculated using a base temperature of + 8^{o} C, which gives an accurate prediction of when migration of the frit fly will take place.

Sclerotinia stem rot (*Sclerotinia sclerotiorum*) is one of the most important diseases on spring rapeseed crops. A method for forecasting the risk for attack by Sclerotinia stem rot has been developed. The method is based upon a number of risk factors, such as crop rotation, inoculum in soil, formation of apothecia from sclerotia, rain fall during early summer and during flowering.

Biodiversity in field scale in Sörmland

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As a farmer's adviser in the region of Sörmland, I have been asked to give my view on the concept of biodiversity and it impact on my work. My first reflection when considering the word is weeds in different crop management systems, and my second thought is the flora of pastures with grazing animals. But as I keep looking at the phenomena of biodiversity in my everyday work life, I begin to realize in how many ways and levels I touch the subject every day, all year round.

1. My year starts up with helping farmers apply for their EU subsidies. Depending on which crops the farmer chooses to grow, the received subsidy varies. The regulations concerning each crop are rigid and the possibility to receive any subsidies at all is conditional upon a huge amount of actions from the farmer. For anyone who is not deeply engaged in the farms and these rules, I think it is very hard to understand how greatly these rules impact which crops farmers grow and the way the grow them. The choices get very limited and it highly impacts biodiversity on a large scale.
2. Field season throws me out among all kinds of weathers, weeds and pests. Here I find "real" biodiversity, and yes, it does depend on the farms crop rotating practice and its use or not of chemicals, but it is easy to see the small differences and miss the big picture. Why is this variety or crop grown in the first place?
3. Planning next year's crops with my farmers is of course based on the specialization of the farm and of basic factors like climate zone and soil properties of the place. Although, in big parts of Sörmland, huge populations of deer and wild boar severely decreases the number of crops you can, if not grow, than at least harvest! Peas, beans and rapeseed, which are all great crops to increase biodiversity in grain strained fields, are not options any more in these places.

Weed suppression by winter cereals: Relative contribution of competition for resources and Allelopathy

Antje Reiss, PhD student at Aarhus University, Denmark
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Weeds are the main reason for potential yield losses in conventional agricultural systems worldwide (Oerke 2006). In recent years, control of weeds only relying on chemicals has become increasingly difficult due to various reasons, such as an increase in herbicide resistance and a more and more limited amount of hemicals on the market, e.g. due to by EU directive 91/414/EEC. Therefore, new means of weed control are needed and one possibility is to take advantage of the weed suppressive effect of the crop itself. During the last centuries, there were no breeding efforts undertaken to increase the trait of weed ompetitiveness in cereals (Andrew et al. 2015). In line with this, detailed information about the traits conferring weed suppressiveness in cereals is lacking.

In my project, I am investigating weed suppressiveness of wheat, triticale and rye. Hereby, special attention is paid to the relative contribution of above ground competition and allelopathic properties in determining weed interference utcome. This will be investigated on cultivars recently on the Scandinavian market in field, semifield and laboratory trials. The above ground traits of the cereals that are investigated are for example early vigour, leaf area and crop height and for the allelopathic interactions the chemical group of benzoxazinoids is in focus. In summary, this project aims to gain understanding of the weed suppressive effect of the winter cereals **wheat, triticale** and **rye** and thereby to add a new technique to the goal of an integrated form of weed management.

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Weed seed germination in winter cereals under contrasting tillage systems

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Grass weeds and *Gallium aparine* are major weed problems in North European arable cropping systems with high proportions of winter crops, especially winter wheat (Clarke et al., 2000; Melander et al., 2008). Problems are accentuated where inverting tillage is omitted, as weed seeds tend to accumulate in the top soil layer and timing of herbicide applications sometimes seems to target the emergence pattern of these weeds poorly.

In contrast to the management of most diseases and pests, weed management should be considered in a time frame. The abilities to produce above and below ground propagules and to infest cultivated land are among the most important features of weeds. The shedding of weed seeds builds up soil seedbank which, in addition to the content of vegetative propagules in the soil, are the principal sources of weeds in field crops (Roberts, 1981).

Several strategies are applied to reduce weed numbers and soil seedbank. However, in recent years Integrated Weed Management (IWM) principles have acquired a stronger place in agriculture (Ghersa et al., 2000; Bastiaans et al., 2008). IWM systems aim at manipulating soil tillage, crop rotation and cover cropping to minimize the impact of weeds. An important component in IWM is to understand and ultimately predict weed emergence patterns in relation to the cropping system and the tillage method applied.

A better understanding of the cumulative emergence patterns of weed species in winter crops under different tillage regimes will help improving the targeting of direct control tactics, whatever they are chemical and non-chemical. This should ensure non-excessive use of herbicides and thus follow the principles of IPM. More specifically, focus should be on the soil layers from which the weed seeds predominantly emerge, their rate of emergence and the interactions between cumulative emergence and the degradation of soil applied herbicides.

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Integrated pest management of two of the most important pests in Swedish greenhouse cucumber production

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This PhD-project began as a participatory research project where growers, extension officers and researchers collaborated to develop integrated pest management strategies against the European Tarnished Plant Bug (ETPB) in cucumber.

In participatory research, people with different backgrounds and experiences collaborate to solve problems within mutual areas of interest. The views of all participants are equally important and they all have the possibility to influence the direction of the project and the methods used. Therefore, great emphasis is put on facilitating interactions within the group. By collaborating in this way, opportunities of finding new broad and sustainable solutions are greatly enhanced.

Between 2011 and 2012 trials were conducted in six different commercial cucumber greenhouses using sunflower as a trap crop. Furthermore, olfactometer trials were carried out where males and females could choose between cucumber, sunflower or lucerne, in different growth stages.

During the project, the group of collaborators met three times annually to discuss and evaluate the project.

Results from both years showed that significantly higher numbers of ETPBs were found on sunflower plants than in the cucumber crop. However, this was not enough to prevent damage.

During the process, it became clear that powdery mildew was an increasingly big problem in cucumber and that the standard fungicide used had lost most of its effect. On the growers' request, the project moved on to investigate integrated pest management strategies to control cucumber powdery mildew. In 2013 and 2015, small scale trials were performed where permitted microbiological pest control products and other non-chemical products were examined. The efficacy of the products will be determined individually and in combinations, with and without fungicides. Both susceptible and partly resistant cucumber varieties are included. Interesting differences have been observed between treatments and varieties. However, as the trial is still ongoing, no results can be presented yet.

Ensuring a sustainable supply of clover seeds – dealing with poor seed set and seed predation

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Clover seed is used in the agricultural sector for animal fodder production and provision of green manure. Currently, production of clover seeds is limited by both poor seed set and seed predation, and variability in seed yield is so great that seed companies are facing acute problems. Shortage of pollinators and recent shifts in pollinator communities towards less efficient pollinator species is a long-term concern for sustainable agriculture. In clover, pollination by long-tounged bumblebees may be most valuable for ensuring a high seed set. Recent studies have demonstrated dramatic shifts in density and composition of bumblebee communities towards more short-tongued species with higher propensity towards nectar robbing. This could lead to lower pollination rates, especially for tetraploid red clover varieties, which have flowers with deeper corolla tubes. Seed eating *Protapion* weevils are identified as important pests in clover seed production, and can reduce seed yield with over 50 percent. Within conventional farming, weevils are effectively controlled by neonicotinoid insecticides, but such insecticides can have negative impact on the essential pollinating bees and are not allowed for use within organic farming. Ecological intensification, where the use of agrochemicals is reduced and the focus instead lies on supporting ecosystem services, is an alternative method to increase production in a sustainable way. In clover seed growing, ecological intensification strategies support pollinating insects and the natural enemies of pest insects, while undermining pests. We explore the possibilities to use spatial planning and ecological intensification to provide sufficient pollination services and control pests in clover seed production, by focusing on the biology and ecology of pollinators, clover weevils, and their natural enemies. Such measures will be particularly useful in the organic farming sector, where most agrochemicals are prohibited, but also in the whole farming sector, to reduce resistance problems and negative environmental impact of agrochemicals.

Sweet potato virus detection, characterization, elimination and management in Ethiopia

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Sweet potato (*Ipomoea batatas*) is a root crop with worldwide importance from the family *Convolvulaceae*. In area coverage and production, it is the third most important root and tuber crop in Ethiopia, next to enset (*Ensete ventricosum*) and potato. At least 20 million Ethiopians use sweet potato as a seasonal staple crops when there is a shortage of other foodstuffs. Plant viruses remains as an important threat to sweet potato production and quality, in particular in Sub-Saharan Africa including Ethiopia. In Ethiopia, studies have shown that most of the sweet potato collections and farmers' fields are infected with viruses. Virus incidence is very high, ranging from 80 to 100 % on maintenance sites and in farmers' fields, respectively. Because of viral diseases, multiplication and distribution of sweet potato plating materials for the millions of poor farmers is spreading diseases rather than contributing to improved yield. Little is known about the virus associated with sweet potato in Ethiopia, production and quality are declining because of no provision of virus free planting materials for farmers. A research project initiative was launched between Hawassa University, Ethiopia and NMBU, Norway financed by Norad (Norwegian Development Agency) under the NORHED program. A sub-project of NORHED (agreement no ETH-13/0017) is working to detect and characterize the viruses, eliminate viruses from farmers preferred sweet potato varieties, evaluate the relative tolerance of the cultivars and thereby improve productivity and livelihoods through providing clean planting materials for the sweet potato growing farmers of Ethiopia. The presentation will present our progress so far in cleaning stocks for viruses and the way forward.

Development of IPM tools for the control of aphids and cereal leaf beetles in grain cultivation

Elias Van De Vijver

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* and the *Oulema gallaeciana* (Coleoptera: Chrysomelidae) 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*; Hemiptera: Aphididae) can interfere with the chemical control of the CLB. For the control of these leaf beetles, farmers often use broad-spectrum pesticides (pyrethrums such as lambda-cyhalothrin). 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 populations and therefore the need for a second application. With the introduction of SUD 2009/128/EC by the European Parliament, January 2014, farmers are obligated (art. 14) 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 DSS (decision support system) based model that predicts optimal timing of application, as well as give an advice to the farmer what selective pesticide to use. This model will 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.

The Heterogenity of Landscape Enhances Species Richness of Ground Beetles (Coleoptera: Carabidae) in Wheat Fields

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In Latvia, family of ground beetles (Carabidae) contains of more than 300 species. The most of them are soil dwelling insects inhabiting all terrestrial habitats. In agroecosystems, ground beetles feed on different pests and weed seeds, thus they are beneficial insects and important elements of integrated pest management.

Studies on ground beetles inhabiting wheat fields were performed from 2012 until 2014 in Latvia University of Agriculture Study and Research farm 'Pēterlauki' (56°30'39.38''N; 23°41'30.15''E). The main objective of these studies were to find out how different management of fields affects ground beetles species community and biodiversity. In a result, it was concluded that not only agronomic activities, but also different landscape elements (e.g. forest patch, river banks etc.) affect ground beetles species community enhancing species richness in crop fields. Two thirds of all captured ground beetles have been identified now, and totally 70 species are recognized. Six of them – e.g. *Agonum gracilipes, Dyschirius aeneus, D. politus* etc. – typically inhabit moist habitats such as banks of rivers and ditches. Another 16 species – e.g. *Pterostichus vernalis, Nebria brevicollis, Notiophilus palustris, Carabus granulatus* etc. – are typical inhabitants of forests. One more recognized species – *Amara plebeja* – inhabits agroecosystems during summer, but overwinters in forests. This species migrates between both types of habitats each spring and autumn. It all allows to conclude that different natural and semi natural landscape elements provide 32.8% of ground beetle species recognized in studied wheat fields. Higher diversity and species richness of ground beetles indicate suitable conditions for them in the crop fields. These parameters also point to presence of appropriate conditions to establish integrated farming.

The study was supported by National Research Programme "Agricultural Resources for Sustainable Production of Qualitative and Healthy Foods in Latvia", project "Sustainable use of soil resources and abatement of fertilisation risks".

Variety mixtures –
Linking interactions between plants and insect pest control

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Biodiversity in agricultural landscapes has been declined rapidly in recent decades with drastically increased extinction rate of species and threatened ecosystem services as a consequence. If biodiversity is to be restored and opportunities created for sustainable food production, cropping systems must optimize functional diversity instead of minimizing it.
Within-field diversification by variety mixtures increases crop biodiversity and enhancing insect pest control through a new mechanism: chemical interaction between plants has been shown to reduce aphid plant acceptance and enhance biological control by natural enemies, opening a way for aphid control in agricultural fields.
The project aims to develop sustainable cropping systems that are resilient to insect pests and enhance functional biodiversity by investigating chemical interactions between plants of different varieties and utilizing responses of those co-existing plants which might result in biological effects.
Volatile signals of plants can be exploited by nearby plants as a cue for competitive neighbors, thus inducing growth responses that increase the competitive power of eavesdropping plants. It has been shown that only certain varieties have this inducing/responding ability, thus a range of potential variety combinations will be screened initially. Plants modify their growth in response to different signals by partitioning biomass between above- and belowground. Promising variety combinations will be chosen to examine if this growth response will change the sugar content in the phloem which can have negative influence for feeding aphids due to quality changes of the responding plants. Differences in host plant quality might affect aphid population development, giving a mechanistically explanation for sustainable pest control in certain barley variety mixtures. Field experiments will assess how experimentally diversified crop vegetation alters resilience against pests and increase biological control potential by natural enemies in order to link crop traits to agro-system services.
Synthesis of the chemical ecology of plants, their physiological responses and resulting effects on insect performance will help to identify mechanisms for sustainable pest control in barley variety mixtures. This will provide policy makers and advisors with vital information about a new sustainable resource for plant protection and enhanced biodiversity in agricultural fields.

Enhanced biological control through non-crop vegetation and semiochemical in Swedish apple orchards.

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The rosy apple aphid (*Dysaphis plantaginea*) and several leafrollers (Lepidoptera: Tortricidae), mainly the eye-spotted bud worm (*Spilonota ocellana*), are important pest in Swedish apple orchards. These pests are commonly controlled with several types of pesticides, but organic orchards are limited to only a few compounds for their control. Natural enemies might help reducing the pest population when less impacting pest control strategies are used, such as horticultural oils or mating disruption. A way of increasing native natural enemy populations and performance is the use conservation biological control strategies. One such strategy is to introduce non-crop vegetation in orchards providing shelter and alternative food sources for the natural enemies.
Non-crop vegetation was sown in 2015 for this purpose. In an attempt to control *D. plantaginea* a non-crop plant with an alternative aphid was established to disrupt there mutualisms with the common black ant (*Lasius niger*). *L. niger* ants, when present, reduce the biological control of aphids as they guard them against their predators. In the following years, herbivore induced plant volatiles (HIPVs) will be used in combination with flower strips to attract natural enemies into the orchards. Flowers strips are intended to promote the establishment of natural enemies in the area for a longer period and increase the overall control of these pests over the years. For the control of leafrollers, these two methods will be combined with mating disruption which already has been shown to reduce the damage caused by this pest in Sweden.

Biannual monitoring of pyrethroid and neonicotinoid susceptibility in Danish pollen beetle (*Meligethes aeneus* F.) populations

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The pollen beetle (*Meligethes aeneus* F.) is a serious pest in the northern countries in oilseed rape. To determine the present level of pyrethroid and neonicotinoid susceptibility of Danish pollen beetle populations, standardized methods recommended by IRAC (Insecticide Resistance Action Committee) were used.

Pollen beetle populations were collected from 47 locations of Denmark with the help of the consultants and the farmers of the various regions in 2014. Further six populations were tested from Sweden and one from Germany.
In the following year 2015, the monitoring continued to find out, if the resistance level which was determined in 2014 was stable in selected regions. Therefore pollen beetle populations from 14 locations in Denmark and five locations in Germany have been tested.

For all tests the standardised methods for pyrethroids, the Adult-vial-test No. 11 and the Adult-vials-test No. 21 for neonicotinoids were used. All glass vials were provided by Bayer CropScience.

In 2014 the tested populations in Denmark were 35 % resistant, about 29 % were classified as moderately resistant, and 37 % were susceptible towards λ –cyhalothrin in the glass vial tests. For thiacloprid, the majority of the tested populations in Denmark, showed a high susceptibility with >95%.

The majority of tested populations in 2015, with λ –cyhalothrin were moderately resistant in Denmark. Further 36% were classified as resistant towards λ –cyhalothrin and 14% were susceptible. For the five tested population from Germany, 60% were moderately resistant and 40 % were resistant. For thiacloprid, the majority of the tested populations were highly susceptible in Denmark and Germany.

The monitoring will be continued next year.

Flowery strips do not enhance predation rate measured by artificial caterpillars in winter wheat (*Triticum aestivum*) fields in Denmark.

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Predation is an important ecological phenomenon. In cultivated landscape, arthropod predation gains further relevance for pest control, but logistical and ecological factors make quantification difficult. One feasible experimental method is the use of artificial sentinel prey, placing a known number of prey items in the field, and calculating either the rate of disappearance or attacks after a set time. Recently, the use of plasticine caterpillars gained attention, as together with predation estimates they inform about predator identity. In Denmark, we used such prey models to test the effectiveness of flowering strips (mix of *Brassica rapa* and *Raphanus sativus*) as habitat manipulation practice to increase biological control. From May to July 2014, we monitored the predator community using pitfall traps and vacuum samplings, and the predation rate along the edges of winter wheat (*Triticum aestivum*) fields surrounded by flowery or grassy strips and within the crop (10m from the edge). Forty-six percent (n=756/1637) of the artificial sentinel prey were attacked after 24 h, mostly by chewing insects (88%, n=665/756), followed by small mammals (13.2%), and birds (1.3%). Predation rate by chewing insects was significantly higher ($p<0.001$) in grassy than flowery margins (48.9%, SD=±24.3 n=30 vs. 30.7%, SD=±17.4 n=25) and significantly higher ($p<0.05$) along edges than within fields (45.3%, SD=±27.3 n=30 vs. 35.9%, SD=±19.3 n=30). In flowery strips, predation was similar within fields and along edges (30.9%, SD=±18.1 n=25 vs. 30.6%, SD=±23.2 n=25), while in grassy ones it was higher along edges than within fields (57.6%, SD=±31.9 n=30 vs. 40.1%, SD=±24.5 n=30).We found a significant positive relationship ($p<0.001$, $R^2=0.50$) between the log-transformed activity density of ground beetles >15mm and predation rate. This type of flowery strips did not enhance predation under Danish conditions.

Impacts of fallow strips on biological control of cereal aphids

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Establishing and managing fallows is a way to promote biodiversity in intensively cultivated agricultural landscapes. Determining the key characteristics of fallows that affect diversity and species composition of wild plants and animals, and associated ecosystem services, would contribute to raising cost-efficiency of the fallowing schemes. In the previous part of my PhD project, I examined how different fallow types and landscape structure modify diversity and species composition of several taxa in environmental fallows in boreal farmland. The results proved that effective fallowing strategies vary depending on the target species groups and the cover of forest and perennial grasslands in the surrounding landscape. Now, I'm studying the potential of fallow strips to contribute biological pest control. As a model system, we use barley and cereal aphids. The impacts of two types of fallow strips – grassland strip and meadow strip – on the biological control of aphids in barley at different distances from the strips are tested in the field experiment. Both fallow strip types are supposed to provide shelter, over-wintering sites and alternative prey for natural enemies of aphids. Additionally, meadow strips were designed to optimize floral food supply for the natural enemies. In the experiment, potted barleys with cereal aphids, as well as aphids glued on self-adhesive labels, are placed into the fallow strips and the adjacent barley fields, and the number of aphids is monitored. Pitfall and sticky traps are used to collect data on the abundances of natural enemies. Preliminary results suggest that, in the first year after establishment, both fallow strip types, and meadow strips in particular, support natural enemies of aphids. However, this has no clear impact on pest control in field.

Can nutrients strengthen plant - predator interactions in agro ecosystems?

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Evidence for the occurrence of strong trophic cascades in terrestrial systems is lacking. This has been suggested to be due to the complexity of terrestrial ecosystems (where several trophic levels and indirect non trophic interactions are widespread) and the lack of strong inputs of allocothonous material compared to stream and lake systems (subsidy theory: Lindman, 1942). Arable systems are generally heavily managed and subsidized in nutrients and organic matter. In addition, their simpler trophic structure compared to many natural ecosystems also offers a good system to investigate the importance of subsidies and trophic cascades in terrestrial ecosystems.

It has been stressed by Polis & Strong (1996) that the functioning of generalist predators as control agents of plant herbivores may be strengthened if they are able to periodically feed on prey from the decomposer community (Holt & Lawton, 1994). One management practice used to improve soil and subsidize decomposers community is the application of organic matter via compost application.

This project aims to test the subsidy hypothesis of Lindeman (1942), that subsidy will lead to an increase in trophic cascade, in an above- belowground multitrophic agricultural systems. We suggest that the outcome of decomposers effect on aboveground food webs and the strength of trophic cascades depend on the nature of amendment. By linking food web dynamics and organic matter budgets we aim to gain more insight in how subsidies can promote production and pest control.

Fungicide resistance analysis of *Zymoseptoira tritici* populations in the Northern Zone

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Over the last decade severe attacks of the wheat pathogen *Zymoseptoria tritici* (STB) has been observed. At the same time several fungicide like the MBC and QoI fungicides have lost their effectiveness due to total resistance. Also for the azole fungicides a gradual declined in efficacy has taken place. In recent years azole fungicides have been seen to be significantly affected by reduced sensitivity to an extent, where field performances against STB in some cases are seen to be insufficient. This is especially unfortunate, since only few products are registered in several of the countries in the Northern zone and no new products are to be launched in the near future. To estimate the risk of fungicide resistance development in *Z. tritici* isolates from Denmark, Sweden, Finland, Latvia, Lithuania, and Estonia were analysed for EC_{50} values for epoxiconazole, prothioconazole, and SDHI boscalid. The presence of mutations in the azole target gene (CYP51), as well as overexpression and efflux were investigated. In addition isolates from 2009 were included to investigate whether a shift in population has been taking place.

Remote plant virus detection

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If future agriculture is to become sustainable in ecologic and economic sense, the use of fungicides, insecticides and herbicides must, for obvious reasons, be minimised. An early response to combat initial infection/infestation minimises the required action and loss of yield, reducing costs and environmental impact. Early detection of pests and diseases thus becomes a key factor independent choice of counter-measure. Most economically important plant viruses are vectored by aphids acquiring virus while feeding/probing on diseased plants then infecting others they later feeds on. Detecting diseased plants and removing them before becoming a major source of virus within the field logically reduces virus propagation. Using remote sensor technology such as cameras and spectrographs it is possible to detect such abiotic and biotic stress within plants in situ. Our project targets potato and will investigate the remotely detectable physiological changes caused by plant viruses, particularly the non-persistent transmitted potato virus type Y (PVY). The virus causes, among other effects, changes to stomatal function, altering transpiration rate and therefore leaf temperature. This can be detected using infra-red imaging. Combining increasingly sensitive cameras and powerful computing platforms it will be possible to detect individual diseased plants which can be treated accordingly. The project is in the initial stages but we hope to deliver usable remote methods for the study and detection of said virus.

Characterization of soil-borne plant pathogens using next generation sequencing

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Soil contains communities of diverse organisms including soil borne plant pathogens that are capable of causing significant economic losses to agricultural crops. The aim of this study is to understand soil microbial communities and their effect on crop health using next generation sequencing. Nematodes, fungi, and oomycetes communities living in cultivated soil were targeted and most of research work is concentrated on carrot and onion. Primers currently used for generating amplicons for nematodes study are not nematode specific and also amplify other groups such as fungi and plantae. We developed an amplification strategy, including a new primer that will selectively amplify nematodes and other metazoans. When tested on DNA templates from a set of 22 agricultural soils, 65% of sequences were of nematode origin in total, whereas the remaining sequences were almost entirely metazoan. Similarly, in oomycetes, standard techniques to study oomycete communities in soil using high throughput sequencing have not been reported yet. Well-known primer sets ITS4, ITS6 and ITS7 had been used in similar studies, but with limited success. We were able to increase retrieved oomycete sequences dramatically by using these primers mainly by increasing the annealing temperature during PCR. The optimized PCR protocol was validated using three mock communities and using total DNA from 26 soil samples collected from different fields. Data showed that the optimized protocol successfully detected all the species of *Pythium* and *Phytophthora* being mixed in the mock communities. Moreover, soil sample data showed that 95% of the total reads could be assigned to oomycetes and was high proportion consistently in 26 samples. Field soil samples planned for carrot and onion cultivation had been sequenced for oomycetes, nematodes and fungi along with disease scoring. Analysis of soil chemical properties such as pH, content of nitrogen, phosphorous, potassium, carbon and many more are being carried out.

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Characterization of nematode pests of Enset (*Ensete ventricosum* Welw. Cheesman) and their management

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Enset (*Ensete ventricosum* Welw. Cheesman) is an important starch staple crop, cultivated primarily in southern and south west Ethiopia. Related to the banana family, enset is similarly infected by plant parasitic nematode. From previous survey studies *Pratylenchus goodeyi* appears to be the dominant nematode pest, which is believed to contribute to reduced productivity of enset. However, while surveys have demonstrated high *P. goodeyi* infection levels, there is relatively scant information on how damaging the nematode is to enset production. There is also little information on the variability of the nematode pest in terms of levels of pathogenicity on enset and if so, how this may relate to variability in climate and temperature zones under which enset is grown. Our study is being undertaken to assess the possible damage of nematode pests, with emphasis on *P. goodeyi*, and in relation to the presence of other diseases and how climate and agro ecology may affect this.

Title: Social Acceptability of Climate Friendly Sustainable Intensification Actions in Plant Production

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My Ph.D. thesis studies social acceptability of climate friendly sustainable intensification actions in plant production. Finland is used as a case study area and the research is based on interview, survey and crowd sourcing materials collected by the researcher. The methods include basic content analysis, qualitative longitudinal analysis and the Delphi method.
As Foley et al. noted in their ground breaking article in 2011, the future needs to see a substantial growth in food production and at the same time a dramatic shrinking of agriculture's environmental footprint. This can be achieved by for example halting agricultural expansion, closing yield gaps on underperforming lands and increasing cropping efficiency.

The Natural Resources Institute Finland will be implementing a European Commission Life funded project called Optimising Agricultural Land Use to Mitigate Climate Change (OPAL-Life) beginning from the autumn of 2015 until 2020. The project is a collaborative effort where the social and economical aspects of sustainable intensification will be studied together with agronomical and environmental ones. The articles for my thesis will be among the deliverables in the OPAL-Life, as I will be working as a researcher in the project.
The key concepts of my research are social acceptability and sustainable intensification. Social acceptability might be differentiated from social sustainability by a focus more on people's values and beliefs and their participation to formulating policy goals and actions. The differentiation of social acceptability and sustainability still needs to be studied further. Sustainable intensification refers to the simultaneous objective of growth in food production and diminishing the stress of agricultural production for the environment.
Joint studies combining all the sustainability sectors in sustainable intensification are still rare. My research will focus on the social dimensions not directly attached to economical ones although closely related to them. I am interested to find out what kind of climate friendly intensification actions are socially acceptable and what are the reasons behind this. The acceptability of climate friendly sustainable intensification actions might depend on culture and tradition bound reasons and also perhaps on differences between generations of agricultural producers.

The social acceptability study has two target study groups: farmers and policy developers (politicians, different interest group representatives and civil servants). The OPAL-Life project will bring together pilot farmers (around 20) from different parts of Finland and three rounds of in-depth interviews will be arranged during the project (2015-2020) to collect data. For the wider farmer community in Finland a survey will be conducted twice during the project lifespan to acquire data from a larger group of farmers. A series of working groups will be arranged to policy developers to discuss sustainable intensification actions and their prospects in the future agricultural policy.

Even the best policy actions to mitigate climate change in agriculture might fail, if social acceptability and the farmer’s views are left out from consideration. Renewal of agricultural practices means at least a partial change in known behavior patterns and it is crucial that we know the farmer’s insights and take them into account in policy planning and execution.

Effects of integrated pest management (IPM) on the population dynamics of the perennial weed species *Cirsium arvense*

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Cirsium arvense (L.) Scop., creeping thistle, is one of the world`s most troublesome weeds and is native to Europe. *Cirsium arvense* might have negative effects on both quantities of the crop yield in the whole cropping systems as well as on fodder quality of hay and silage. It is a perennial weed with a deep and wide-spreading root system which ensures survival and rapid vegetative spread under a wide range of soil and management conditions.

Weed control strategies may be classified into different categories which include physical, cultural, chemical and biological weed control strategies. Physical control emphasizes mechanical techniques such as soil tillage and mowing. Biological control is the use of living organisms to suppress weed infestation, while chemical methods by means of herbicides are used to control weeds. *Cirsium arvense* is usually efficiently controlled by herbicides such as MCPA. However, since the European Union issued a directive in 2009 which promotes non-chemical control methods, conventional farmers are being compelled not to solely depend on chemical control but to consider integration of different weed control systems which encompass chemical, cultural and physical methods.

In this research project, studies are being done on how different combinations of mechanical and chemical control strategies coupled with crop competition (cultural method) affect the growth and development of *C. arvense* and how these methods can be used to develop a sustainable and effective control system.

Preliminary results have shown that timing i.e. when to employ the control strategies is an important aspect in developing an effective IPM system.

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