# Strategy Document of Department of Plant Protection Biology 2017-2020

## 1. Department's role and profile

The Department of Plant Protection Biology is an interdisciplinary constellation with good opportunities for strong research collaboration within and outside the departmental area. Leading research is conducted in resistance biology, integrated plant protection and chemical ecology to develop the understanding and sustainable use, as well as management of biological resources. The research efforts are directed towards both basic and applied research. Applied plant protection research is carried out in collaboration with industry and primarily focuses on the development of environmentally sustainable pest control strategies for agriculture and horticulture, both in Sweden and internationally.

The department's strength lies in the combination of solid basic research and well-developed applications relating to the need for knowledge, competence supply and innovations in the field of plant protection biology. As such, we contribute to develop plant protection research at SLU, and to the university-wide domain concerning the national food strategy.

The strong integration between research and education strengthens our course curriculum and student performance at undergraduate and graduate levels. Our department provides high quality teaching in central areas, including plant protection, plant biology, chemistry and ecology. The teaching links the scientific progress within the respective fields and with the needs of the students to further their careers.

## 2. External conditions

Society is facing major challenges linked to globalisation, urbanisation, sustainability and climate changes. These challenges entail new requirements and expectations of SLU as a knowledge developer. Many of the UN's Sustainable Development Goals (Agenda 2030) concern the management of biological resources. To secure the food supply, a transition to a bio-based economy is necessary, with sustainable production systems, safeguarding biodiversity, reducing poverty, sustainable food consumption, health and a good local environment. These issues are all central to the department's strategy.

The Integrated Pest Management directive of the European Union entails a reduction of pesticide use in agricultural and horticultural production and a need for the development of alternative and sustainable methods to control native and invasive pests and pathogens. This challenge is important to ensure food security, including quality and health, in existing agroecosystems, as well as in urban areas. A change in research policy, as well as stakeholder and public engagement will be required for the full implementation of the EU directive.

At SLU, plant protection, with a system perspective, needs to be included in the curriculum across many educational departments to meet the national and international challenges.

# 3. Department's subject areas

## 3.1. Resistance biology

***Description of the competence area***
The objective of the Resistance Biology Unit is to meet the future reduction in chemical fungicides, and the effects of climate change that lead to an elevated risk of plant diseases. This will be achieved through optimisation of the relationship between return and effort in agriculture by creating a foundation for refining plant disease resistance and decision support systems. Our research primarily focuses on how plants defend themselves against pathogenic oomycetes, fungi and bacteria. We are also interested in causal evolutionary forces in the interaction between pathogens and plants and how different stress paths interact to create resistance that is more stable over time.

Our competencies can be divided into the following sub-categories:

**Resistance mechanisms and sensitivity –** Our primary focus is potato late blight caused by *Phytophthora infestans*, one of the most devastating plant pathogens. In Swedish agriculture, almost one third of all fungicides are used against this disease. There is a great need for several novel resistance mechanisms. We work on resistance to this disease and collaborate with potato breeders. The resistance mechanisms are investigated by identifying and characterising proteins that are part of the interaction between *Phytophthora* and the plant. We do this by means of proteomic and transcriptome analytical studies as well as with microscopical methods. Hypotheses are tested by expressing candidate genes in transgenic plants and through classical biochemistry, both in controlled conditions and field trials. We also investigate two other potato pathogens: *Alternaria* and *Dickeya.* These are used in comparative studies with *Phytophthora,* for example with signalling mutants. We have also begun to study interactions between multiple organisms.

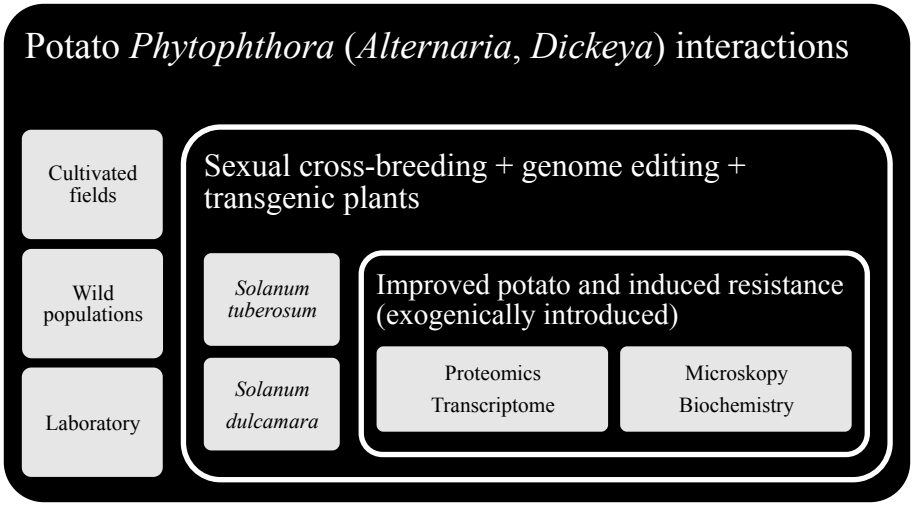
**Plant resistance inducers –** To achieve a sustainable effective plant protection strategy, different methods have to be integrated. We conduct applied experiments with induced resistance in greenhouse and in the field combined with classical fungicides. We are also interested in co-cultivation systems that are used in systems with integrated plant protection (Integrated Pest Management, IPM). Plant protection products with low toxicity and biological pesticides are also of interest.

**Evolutionary forces in antagonistic interaction at population and field level –** We study plants' defences and pathogenicity by combining biochemical and genetic knowledge with theories on ecology, evolution biology and resistance biology. This is done for example for Swedish populations of *Solanum dulcamara* and the pathogens *P. infestans* and *Alternaria solani*.

The current focus is to conduct strategic important basic research in combination with applied aspects within resistance biology.

***Overall aim***
Our primary objective is to create a knowledge base aimed at balancing the evolutionary arms race between the plant and *Phytophthora* and other important pathogens, in the plant's favour. To create a sustainable system that can provide cultivated crops with effective resistance properties, there is a need for **many novel sources of resistance**. One overarching

aim is to combine basic research and applied research within resistance biology and combine laboratory and field studies. Relevant high-quality research requires a focus on a small number of limited sub-areas.




## 3.2. Integrated plant protection biology

***Description of the competence area***
Food production is facing a number of challenges arising from global changes to the environment and society. The development of sustainable farming systems is necessary to meet these challenges. Integrated Pest Management (IPM) is an ecosystem-based, interdisciplinary strategy that focuses on long-term prevention of plant diseases and pests or their damage through a combination of measures such as biological control, chemical control and cultural practices. Pest control methods are selected and applied in such a way so as to minimise risks to human health, beneficial and non-target organisms, and the environment. IPM is highly desirable due to its environmental and economic benefits, and the EU directive (2009/128/EC) implemented since 2014 mandates that IPM shall be used in all agricultural pest control. Clients for IPM departments include large- and small-scale practitioners of agriculture, horticulture, and gardening, both professional and public. However, there are still significant knowledge gaps that prevent the use of IPM.

Implementing IPM involves iterative interaction between basic laboratory research, field trials and multiple stakeholders to foster co-learning in innovation. The design of optimal integrated pest management strategies is an interdisciplinary research activity that bridges the gap between theoretical and applied ecology and requires field-applied science based on ecological theory. Therefore, the ecology of relevant pests and diseases and their interactions with the aboveground and belowground components of the crop management system need to be well understood. Such an interdisciplinary approach requires the development and the refinement of collaboration within the research group.

**The Integrated Plant Protection Unit** has developed a broad and deep knowledge in IPM that links basic and applied research by collaboration within the working group and with groups at other institutions within and outside Sweden. By designing research strategies that embrace all the steps, from multi-stakeholder research question definitions through the acqui-

sition of basic knowledge to the transition to the field situation and collaborative stakeholder evaluation of results, we generate novel opportunities for a safe pest management.

**The Integrated Plant Protection Unit** conducts research in direct connection with practitioners and agricultural development actors and is responsive to their input. We conduct basic research to address knowledge gaps that relate to applied problems, and we interact with stakeholders to explore new opportunities for sustainable and resilient pest management, and for the implementation of our research. Currently, we interact by using participatory action research methods within the context of pest management research. Teaching activities have been closely linked to basic as well as applied research in order to prepare the students to play important roles in future sustainable plant protection.

The objective of our research is to improve IPM programs through the incorporation of tools such as biological control, cultural practices, semiochemicals, crop resistance, decision support tools, participatory research tools and ecosystem engineering within cultivation systems. In order to fulfil our mission, we are carrying out laboratory, semi-field, field and social science research from an agro-ecological perspective. This approach allows for both developing new practical applications and testing new ecological hypotheses. Broader goals, such as preservation of biodiversity, ecosystem services and food safety, are achieved through the implementation of our results. The ultimate goal is to co-create new pest management departments in cooperation with end-users and thereby increase IPM adoption.

***Overall aim***

- Develop sustainable agro-ecosystems with resilience to pests and diseases based on ecological theory and the needs of current and evolving agriculture.
- Develop interaction with stakeholders such as practitioners and agricultural development actors within the context of pest management based on learning and action theories
- Develop teaching activities in plant protection.

## 3.3. Chemical ecology horticulture

***Description of the competence area and overall aim***

The ultimate goal of our research is sustainable and secure food supply. We investigate how insect sex pheromones and other semiochemicals of plant and microbial origin are coded by the insect olfactory circuitry and how these semiochemicals can be used to manipulate the behaviour of beneficial and noxious insects for sustainable pest control in horticultural crops. Animal-microbe-interactions are a current research focus. The identification of chemical signals mediating cross-kingdom communication is fundamental for understanding the ecology of horticultural production systems. This work leads to development of novel insect control techniques. Furthermore, research on animal-microbe-interactions informs us about the contribution of microorganisms to the sensorial quality of horticultural crops and their products.

**Animal-microbe interactions**

Microbes interface animals with plants. Associations between microorganisms and plant-feeding animals are widespread, and we have just begun to recognise their outstanding role and impact. Aided by new tools in analytical chemistry, molecular biology, bioinformatics and insect sensory physiology, this field provides a rich substrate for innovative research.

Microbes associated with plants and plant-feeding insects provide opportunities for novel strategies to control insects. In addition, microorganisms essentially contribute to the sensory quality of horticultural products.

**Insect control**
In a changing climate, we are increasingly challenged by invasive species. Moreover, we are called to contribute to plant protection in developing countries. We therefore work with both native and exotic pests. Building on pioneering studies of microbial mutualists in codling moth *Cydia pomonella* and the fruit fly *Drosophila melanogaster* during IC-E3, we now use this knowledge for the development of novel pest control strategies. One main target is the spotted wing *Drosophila*, *D. suzukii,* which is the number one pest of soft fruit and berries in Europe and North America. The taxonomically related tephritid fruit flies are widely distributed in temperate and warmer climates. Sustainable and more efficient control contributes to mitigate the effects of climate change and to improve food security in threshold countries. We also continue to study other insect herbivores of horticultural crops, such as codling moth.

**Sensorial quality**
The discovery that our main study insects are closely associated with microorganisms and that they respond to microbial signals affords a diversification of our scope and aligns particularly well with continued interactions with fruit and wine growers. Chemical analysis of microbial metabolites demonstrates their essential contribution to the sensorial quality of fruits and berries. Moreover, the presence of detrimental microbes can also be detected via volatile chemical signals.

We currently make efforts to extend our toolbox to the study of human odorant receptors and expect this work to become increasingly important in our future research. In this context, we plan to extend comparative studies of odorant receptors in insects and vertebrates to the functional level.

***Research goals***
- Advance chemical ecology research in horticultural insects and animal-microbe interactions.
- Maintain and advance our competence in analytical chemistry, molecular biology, bioinformatics, sensory and behavioural physiology.
- Bring our work to practical application and thus make a contribution to society. Our joint-stock company, Phero.Net AB, facilitates patent applications, registration of insect control methods and interactions with growers via Partnerskap Alnarp.

## 3.4. Chemical ecology agriculture

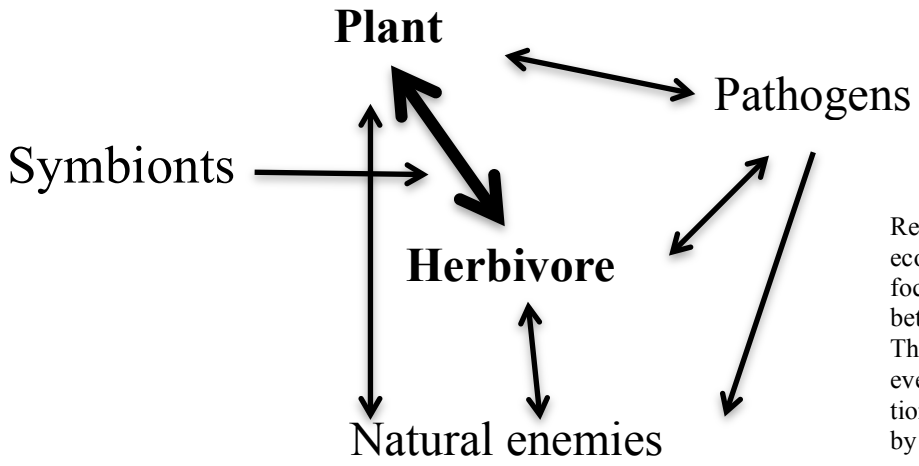
***Description of the competence area and overall aim***

Interactions between plants and insects are important in all habitats, both natural and those created and enriched by humans. Chemical signals are of great importance in these interactions. Plants produce many different chemical substances that affect the ecological interaction with other organisms and underlying evolutionary processes. We study how plants, and plant odours in particular, control insects' behaviour. We also investigate causal sensory processes, such as physiological and molecular mechanisms.

Within the subject area we further develop basic research based on society's needs, with a focus on national and international collaboration. Knowledge of interactions between plants, insects and associated organisms, controlled by chemical signals, constitutes a platform for novel, environmentally safe applications to meet society's growing demand for sustainable production and food safety. Together with knowledge of chemical signals between insects, *i.e.*, pheromones, knowledge of interactions between plants, insects and other organisms that affect these interactions will be a cornerstone of modern IPM strategies. This knowledge will be used to develop methods for agrarian systems, but the knowledge is in many cases general and can also be applied in horticultural systems, as well as in forestry and nature conservation, with the aim of reducing the use of pesticides.

**Main fields of research**

Research in the subject area is dominated by studies of ecological interactions between plants and herbivorous insects, where chemical signals are important. The interactions are also studied in a multitrophic context, where the influence of other organisms (pathogens, symbionts and natural enemies) associated with plants and insects are investigated. One important aspect we focus on is modulation, where insects' plasticity of behaviour and physiological reactions are studied on various scales ranging from cell to habitat. We also study how odours exuded by both host plants and non-host plants affect insects' choice of host plant and how a greater diversity of odours in habitats with high biodiversity contributes to reducing pest attacks. Expertise in chemical analysis is important to be able to identify the olfactory substances that affect behaviour. Important research is also being conducted on the preservation of biodiversity alongside studies of mechanisms that control the spread and establishment of invasive species. Initial studies are also being made of various kinds of 'omics' to investigate mechanisms behind ecological interactions and evolutionary changes. A number of studies are being conducted in collaboration with low-income countries to solve specific problems in these countries.




Research in chemical ecology - agriculture: The focus is on the interaction between insects and plants. These interactions, however, do not occur in isolation but are also affected by interactions with other organisms.

## 3.5. Disease vectors

*Description of the competence area and overall aim*

We study the chemical ecology, ethology and evolution of disease vector insects. We conduct and promote basic research on the chemical ecology of disease vectors in accordance with societal needs, nationally and internationally, and apply this know-how to develop novel surveillance and control tools to be used within the integrated vector management frame-

work. Our multi-disciplinary approach, to study how odour-mediated behaviours of disease vectors are modulated by external chemosensory cues and internal physiological states, is directed towards the identification of targets for reducing host-vector interactions.

Our main research topics cover aspects relating to the multifaceted ecology of adult disease vector mosquitoes:

**Sugar-seeking**
Plants produce an abundance of chemicals that shape the ecology and evolution of their interactions with mosquitoes. We are interested in identifying the natural sugar sources and their inherent components, and to study the olfactory and gustatory processes of how these plant chemicals affect mosquito behaviour, including the underlying physiological and molecular mechanisms, and the state dependency of these processes. Our *projected outcomes* include the development of inputs for bait-and-kill/contaminate devices and strategies.

**Host-selection**
Mosquitoes select and discriminate among vertebrate hosts based on species-dependent chemical signatures. We investigate the variety and specificity of the host volatile chemistry in an ecological context, across mosquito species differing in host preference. We explore the mechanisms generating and modulating these behaviours at the molecular and neuronal levels, and their dependence on internal and external factors. Our *projected outcomes* include the development of attractive lures and spatial repellents based on host and non-host volatiles.

**Oviposition-site selection**
Mosquitoes use cues from within the landscape over varying distances to locate and discriminate among suitable egg-laying sites. We investigate the variety and specificity of the odour space surrounding these sites within the ecological context of the landscape. By studying oviposition site preference across species, we aim to uncover the adaptive processes by which these preferences have evolved. Our *projected outcomes* include the development of attractive lures to be used in gravid traps and other devices based on ecologically relevant habitat volatiles.

**Modulation**
Mosquitoes display state-dependent odour-mediated behaviours. We aim at describing the molecular effectors involved in this phenotypic plasticity through the functional connection between gene expression and behaviour. We also aim at identifying the endogenous signals regulating neuronal and behavioural sensitivity to ecologically relevant resources. Our *projected outcomes* include the identification of key chemosensory-related genes and regulatory elements that could be targeted in future vector control programmes.

## 3.6. Extension within plant protection

SLU has traditionally played a central role in gathering knowledge and supplying extension services for plant protection in agriculture, forestry and horticulture. Over recent decades, SLU has had a broader role in basic research related to agriculture and forestry, and advisory services in plant protection are today provided by other organisations, in the public and the private sectors.

In line with recommendations from the latest international assessment of SLU (KoN 09, Kvalitet och Nytta), SLU has made a priority of extension work, in part by the appointment

of a number of extension lecturers. Partnership Alnarp benefits from collaborations with the production-orientated parts of the sector, and serves as a platform for collaboration within plant protection for relevant research questions.

The department has a comprehensive collaboration plan to improve contact with partners in the plant protection community and to raise awareness for SLU's current role and mission. We will, in collaboration with partners in the sector and other interest organisations conduct research within plant protection, which can yield new solutions to present and future crop protection problems and contribute to the sustainable development within plant protection.

***Resources***
One of the SLU extension lecturers is placed at the department (Erland Liljeroth) and the deputy head of department (Åsa Lankinen) has allocated time for extension work.

***Goals***

- Establish and develop contact with public and private partners within plant protection organisations and environmental organisations through regular invitations to seminars on the research within the department. Further, to actively organise activities related to plant protection, such as workshops with stakeholders and international meetings on specific crops and/or issues.
- Encourage researchers at the department to partake in extension activities and thereby increase the visibility of our researchers in relevant arenas, and to produce popular science literature for the plant protection sector.
- Seek financial support for more applied research projects of high quality within plant protection and further develop partner-driven research where growers and advisors partake in the research.
- Stimulate researchers from other disciplines, including technology/engineering, agricultural science and biology to collaborate in plant protection research.
- Develop high school-level extension through encouraging visits from school classes and offering placements and school projects for interested students.

# 4. Operations

## 4.1. Research

The department encourage collaboration between subject areas within the frame of available resources. Increased collaboration is prerequisite to further develop research and teaching within plant protection.

## 4.2. Doctoral education

At the time of writing, the Department of Plant Protection Biology has 14 active doctoral students within the five subject areas.

We aim to attract national and international applicants to doctoral student positions, and to offer a strong research based education. In order to ensure that the level of supervision is of high quality and to achieve a broad competence, each doctoral student will have a main su-

pervisor and at least two additional assistant supervisors. In addition, each student should be attached to a research school and partake in international conferences in order to develop a wide contact net. One clearly expressed goal is that doctoral students should get increased opportunities to take part in teaching at undergraduate and MSc level in order to gain pedagogic experience and skills.

During the period of their studies, doctoral students should participate in basic and subject courses to strengthen their competence and widen their perspective of plant protection biology. The department will ensure to continuously offer established international doctoral courses, and to develop new courses, in collaboration with other departments, when needed. Our goal is that the doctoral thesis shall be of high quality and contain articles that are widely appreciated and cited within their subject area. An additional goal is that the knowledge and skills of our doctoral students shall make them competitive in the market for academic jobs or a career in another sector.

## 4.3. Courses at undergraduate and graduate level

The Department of Plant Protection Biology participates in teaching at all undergraduate professional programs based at campus Alnarp. The majority of teaching is associated with educational programs in horticulture, but significant contributions are also made to programs in agriculture, landscape engineering and landscape architecture. Our commission includes course responsibility for undergraduate courses in ecology and chemistry and on advanced level, courses in practical research training, insect chemical ecology and integrated pest management. In addition, we are engaged in the Agroecology Master´s programme, with course responsibility for the first course in the program.

Our teaching reflects the research conducted at the department with plant protection, ecology, chemistry and plant biology as main subjects. We actively strive to provide teaching of high quality and to strengthen the teaching-research linkage both in undergraduate and graduate courses and programs. Teachers are encouraged to use a great element of flexible learning and different pedagogical methods to stimulate student activity and participation. All courses include key sustainable issues to promote education for sustainable development (ESD) and encourage critical thinking and other transferable skills. Student feed back in course evaluations is continuously used as a tool for improvement of educational quality and to ensure stimulating learning environments. Dialogue with department coordinators is encouraged in order to develop course contents and training of generic skills in a holistic way, taking in account progression in the different educational programs.

The department aims to broaden teacher´s competence and support lecturers in their ability to reflect on their teaching for professional development by encouraging participation in higher education competency courses provided by the Educational Development Unit (EPU). Participation in pedagogical activities on campus, such as teacher's lunches, is encouraged. With examples from their own teaching practice and shared experiences with other teachers, lecturers are encouraged to compile a teaching portfolio for the assessment of teaching qualifications for their future career development.

The department is part of the active educational academia with excellent teachers that will support educational development at SLU (SLU strategy 2017–2020).

### Goals

- Increase the volume of teaching in plant protection, especially at the undergraduate level in landscape programmes.
- Increase the volume of teaching, especially at Master´s level, within the area of environmental and sustainable production and areas associated with health and food quality (SLU´s profile areas).
- Develop courses within our specialist fields together with universities and research establishments in developing countries.
- Increase international mobility for teacher and student exchange.
- Increase the number of supervised bachelor's and master's degree projects.
- Increase the number or people involved in teaching, especially junior scientists.
- Ensure that there are enough staff for high quality teaching in undergraduate courses, especially in plant protection.
- Develop course quality to attract more students.
- Ensure dialogue with department coordinators.
- Set aside working hours for teaching staff for regular continued professional development.
- Establish a plan to ensure employees´ opportunities for continued professional development.

## 5. Focus areas

### 5.1. Employees

Create a good and creative work environment in concrete actions and behaviours with the support of SLU's core values.

- Each subject area will actively work to meet the challenges raised in the employee survey.
- The department will offer a full health examination to all co-workers on a regular basis.
- All employees working in laboratories will partake in laboratory safety instruction courses.
- The department and subject area leaders will actively encourage all co-workers to participate in joint department meetings and social activities.
- Each subject area will offer regular lab tours to present ongoing research.
- Each subject area will be responsible for the presentation of ongoing activities on individual web sites.
- Each co-worker will provide individual CVs on their personal web pages.
- The department will organise and offer a mentorship department for postdocs and young researchers, supported by the LTV Faculty.

### 5.2. Students and education

- Initiate teachers' meetings on a regular basis at the department to discuss and systematically improve course content, concurrence and quality, and to better use available competence.

- The head of department will set aside working hours for teaching staff for regular continuing professional development.
- The head of department will establish a plan to ensure employees´ opportunities for continuing professional development.
- Increase communication between departments, department coordinators and Board of Education to improve and develop course curricula, and participate in the department development.
- Utilise analysis of undergraduate education performed by the Plant Protection Platform as a basis for further discussions on how to increase plant protection in the curricula of other education departments.
- Increase international mobility of teachers and students.

## 5.3. Research infrastructure

- Contribute to the inventory of basic infrastructure at SLU.
- Apply for SLU research infrastructure funds, with other departments if required.

## 5.4. External collaboration

- The department will contribute financially to enhance international collaboration, based on available resources.
- The department will encourage extension collaboration.

## 5.5. Our shared SLU

- The department will ensure that co-workers have knowledge of SLU as whole.
- All employees should be involved in discussions on how their own activities contribute to the whole of SLU and how collaboration and/or coordination within the university can be developed. The department and all subject areas will conduct ongoing, broad discussions on the manner in which they contribute to SLU's profile and objectives.