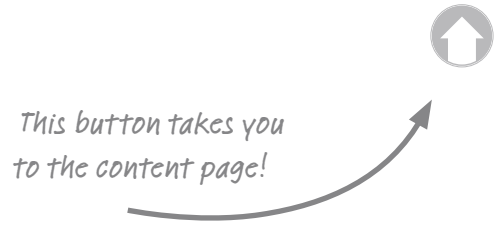
Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Mistra Biotech
Annual Report 2016

MISTRA Biotech



Mistra Biotech

Annual Report 2016

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MISTRA
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SLU

The world faces major challenges associated with our environment, human use of natural resources and our impact on our surroundings. The Swedish Foundation for Strategic Environmental Research (Mistra) plays an active part in meeting these challenges by investing in the kind of research that helps to bring about sustainable development of society.

This is done by investing in various initiatives in which researchers and users make joint contributions to solving key environmental problems. Mistra's programmes cut across disciplinary boundaries, and the results are intended to find practical applications in companies, public agencies and non-governmental organizations. For more information, vistit www.mistra.org.

Chair's preface

A few weeks ago I had the privilege of being one of the organizers of a seminar on sustainable agriculture arranged together by the two Royal Academies, the Royal Swedish Academy of Engineering Sciences (IVA) and the Swedish Royal Academy of Agriculture and Forestry. We had interesting discussions with leading experts who presented different perspectives on today's agriculture. Our approach was global, and there can be no doubt that on a global scale, food production faces great challenges. We need to feed the world's population, and this has to be done in a sustainable way that avoids further damage to ecosystems and biodiversity. In order to meet these challenges we need to combine many fields of knowledge, and make use of experience from many kinds of agriculture around the world. Unfortunately, neither conventional nor organic farming has all the answers. One thing they have in common is that they both need the resources of modern plant breeding to solve their problems.

At the time of writing, the Swedish Government has just presented its new strategy for food production in Sweden. Although its perspective is Swedish rather than international, the basic conclusions are very much the same. The strategy puts emphasis on plant breeding. A national competence centre for plant breeding is going to be created in order to provide research and technological development in the area. More support will be given to Nordic co-operation in plant breeding. There will be a focus on developing suitable crops for all parts of Sweden, and support will be given to the reintroduction of traditional cultivars in order to increase biological diversity. All of this is very much in line with what Mistra Biotech is already working with.

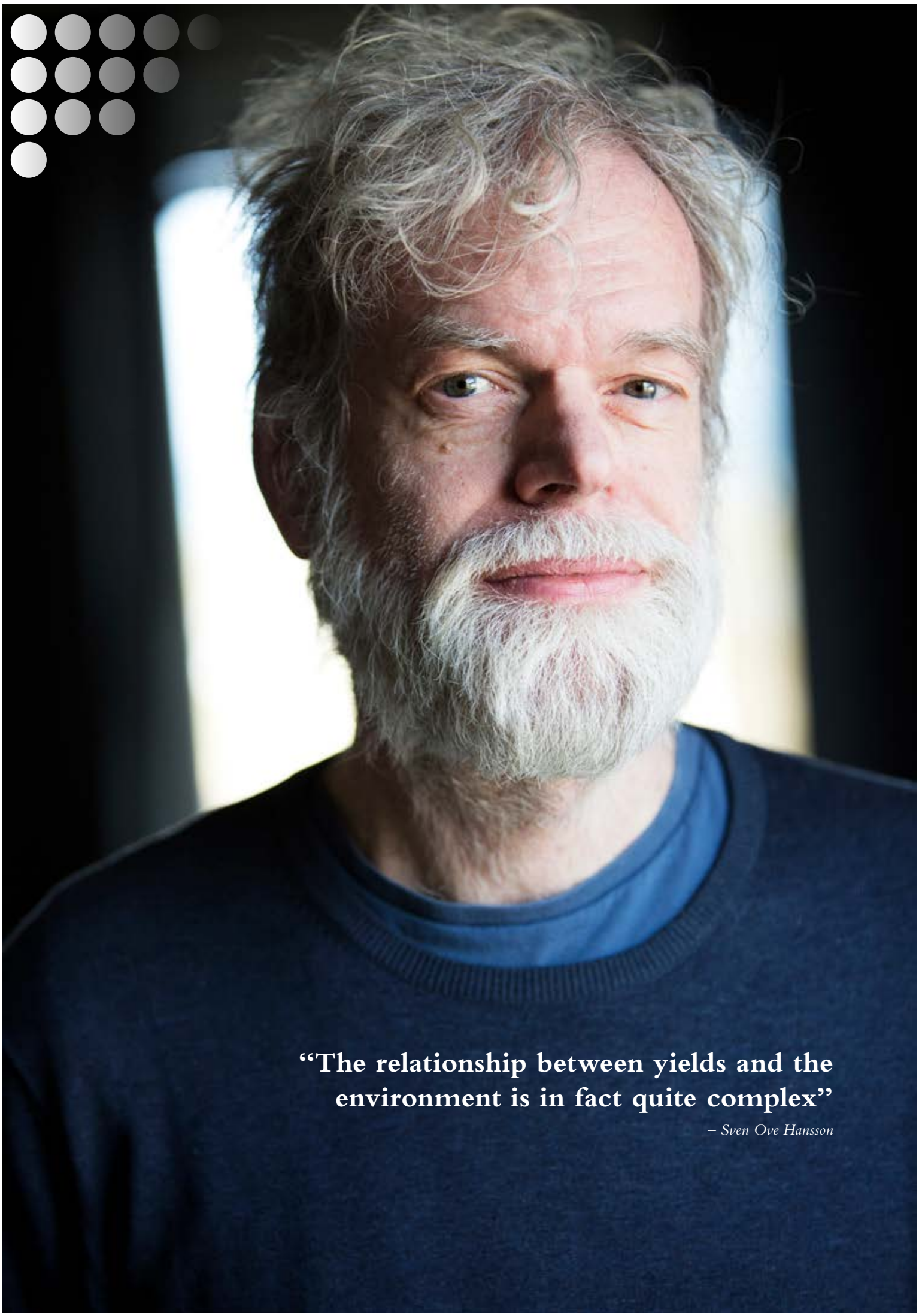
One thing I have learned from Mistra Biotech is how much we depend on international co-operation and exchange of information in the area of plant breeding. It is true that agriculture differs much between countries and regions. Crops and cultivars must be developed and selected for local conditions, not least in terms of climate and local food traditions. However, the fundamental problems that have to be solved are very much the same all over the world. We need to find ways to make agriculture more environmentally sustainable, while at the same time guaranteeing social and economic sustainability for those who earn their living from it. No country alone has the research capacity needed to develop the means for sustainable agriculture, but together we can do it.

Today, agricultural research is international to a very high degree. In Mistra Biotech, we have researchers not only from various parts of Europe but also from Africa, Asia, and Latin America. International co-operation and exchange is a necessary component in our research.

We need co-operation not only with researchers but also with farmers. They know better than anyone else what problems agricultural researchers should solve, for instance what traits plant breeders should aim at. At the seminar I mentioned in the beginning we listened not only to scientists but also to a farmer who told us about her experiences from ecological agriculture. Co-operation with farmers is also important in Mistra Biotech. For instance, at the latest board meeting we learned that a farmer from Northern Sweden had become so interested in field cress, our new oil crop, that he contacted the researchers and offered to make a small field trial on his own farm.

Sustainable agriculture must be built on many types of knowledge and experience. We need to combine the knowledge of farmers, both organic and conventional, plant breeders, ecologists and other natural scientists, economists, consumer researchers, ethicists, and experts in several other areas. Furthermore, this must be done on an international scale, making use of experience from agriculture all over the world. This is a truly co-operative exercise, and that is one of the reasons why it is both exciting and rewarding to follow this research closely.

Inger Andersson
Chair of the Board, Former Director General of the Swedish National Food Agency



“The relationship between yields and the environment is in fact quite complex”

– Sven Ove Hansson

Do we need higher yields?

In discussions about the environmental problems in agriculture, the "chase for higher yields" is often the target. Many discussants see the demands for higher yields as the main underlying problem. And to some extent they are right: Some of the technologies that are used to increase yields have considerable negative effects. Pesticides have saved many harvests, but they have also caused considerable damage to nature and in many parts of the world also caused health problems for the growers and their families. In many countries, insecticides are still used that cause considerable harm to non-target insects, including pollinators such as honeybees that are essential both for agriculture and for the wild flora. Environmental problems are also created when yields are increased by irrigating beyond the capacity of local water supplies or fertilization to an extent that leads to eutrophication of surrounding waters.

But that is only one part of the story. The relationship between yields and the environment is in fact quite complex. I will not try to give the whole picture, but let me point out three facts that we need to keep in mind in these discussions.

The first of these facts is that *there is no direct or unavoidable connection between increased yields and environmental damage*. Some measures that increase yields are negative for the environment, but there are also ways to increase yields that are positive for the environment, or at least only have comparatively small negative effects. Clear examples of this are crop rotation and mechanical and biological pest control, and the use of cultivars with improved tolerance to environmental stresses such as drought, flooding, high salinity, high and low temperatures, and various pests. And of course, we serve the same purpose by reducing the large losses that take place in all parts of the food chain.

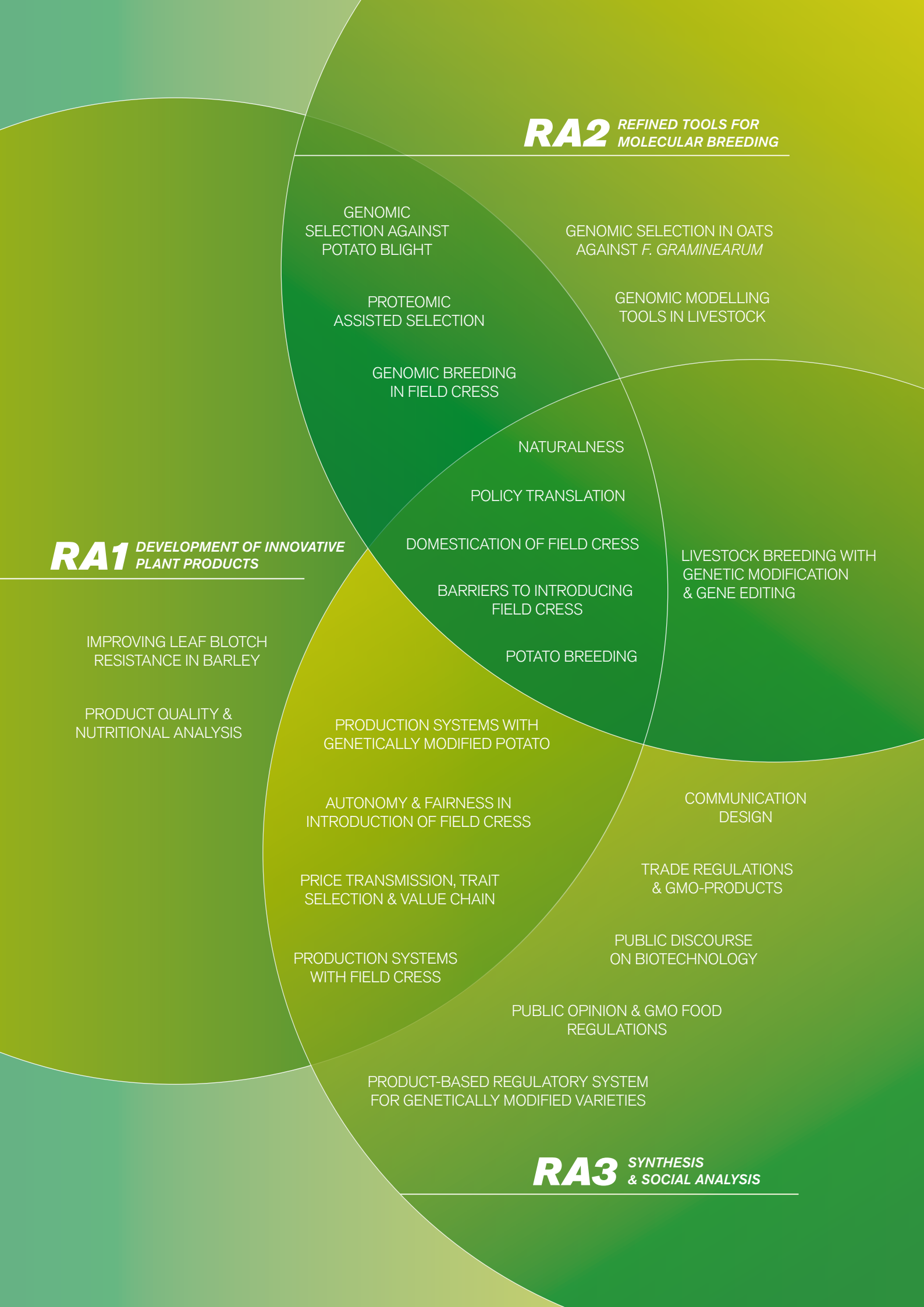
The second fact is that *the global environmental impact of agriculture depends to a large extent on the total area used for farming*. Natural habitats are already so curtailed that a further large-scale expansion of farmland is bound to have devastating effects. If we improve yields on the already cultivated lands in environmentally friendly ways, then this is a double win situation – we reduce the environmental impact on the already cultivated area, and at the same time we save wilderness from cultivation. (Needless to say, our need for farmland is also much influenced by what types of food we choose to eat.)

The third fact I want to emphasize is that *plant breeding and modern biotechnology can provide us with environmentally friendly ways to increase yields* and thus achieve such a double win situation. One important example is resistance breeding that results in crops capable of resisting pests without the application of pesticides. Resistance breeding can take the form of "back-to-nature" breeding. For instance, a potato variant can be made less susceptible to pests if it is provided with resistance traits that have since long been lost due to breeding that selected for other traits. Thanks to modern biotechnology, plant breeders have efficient tools for resistance breeding.

Another important example is breeding for more efficient use of nitrogen. Plant breeders are currently investigating several traits from wild species that would improve the uptake of nitrogen from soil, or its metabolic use. These can potentially be ways to reduce the use of fertilizers, thereby bringing down eutrophication. Other interesting plant breeding projects aim at improving draught tolerance and photosynthetic efficiency.

In summary, increased yields can be obtained in ways that are bad for the environment, but they can also be obtained in ways that are good for the environment. Plant breeding and modern biotechnology can provide us with new ways to combine improved yields with environmental improvement.

Sven Ove Hansson
Programme Director, Professor in Philosophy at the Royal Institute of Technology (KTH)


RA2 REFINED TOOLS FOR MOLECULAR BREEDING
GENOMIC SELECTION AGAINST POTATO BLIGHT
GENOMIC SELECTION IN OATS AGAINST F. GRAMINEARUM
PROTEOMIC ASSISTED SELECTION
GENOMIC MODELLING TOOLS IN LIVESTOCK
GENOMIC BREEDING IN FIELD CRESS
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DOMESTICATION OF FIELD CRESS
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BARRIERS TO INTRODUCING FIELD CRESS
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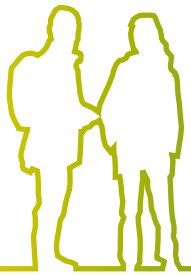
PUBLIC OPINION & GMO FOOD REGULATIONS
PRODUCT-BASED REGULATORY SYSTEM FOR GENETICALLY MODIFIED VARIETIES
RA3 SYNTHESIS & SOCIAL ANALYSIS

Mistra Biotech

Mistra Biotech is an interdisciplinary research programme focusing on the use of biotechnology for sustainable and competitive agriculture and food systems. Our vision is to contribute to the processes that will enable the Swedish agricultural and food sector to produce an increased amount of high-quality, healthy food at moderate costs with less input, decreased environmental impacts, and healthier crops and livestock. The goal is sustainable production systems from ecological, social, and economic perspectives. We perform research in both the natural and the social sciences.

Our research in the natural sciences is aimed at utilizing the potential of agricultural biotechnology to contribute to a more sustainable food production with healthier products and reduced environmental impacts. With ability comes responsibility, and we take the concerns that have been raised about potential negative effects of biotechnological products on human health and the environment very seriously. For us, safety, control, and transparency are essential regardless of which technology is used.

Our research in the social sciences involves social, economic, and ethical aspects of the use of biotechnology in agricultural production, with a strong focus on sustainability issues and on the perspectives of stakeholders in the food production systems. The first phase of the programme started in 2012. During 2016 the programme entered its second phase (2016-2020) and reorganized its research in order to put more emphasis on programme synthesis and policy issues. Mistra Biotech now consists of three research areas (RA): RA1 Development of innovative plant products using modern breeding tools, RA2 Refined tools for molecular breeding, and RA3 Synthesis and social analysis.



Mistra Biotech involves about 60 researchers. Most are at SLU, but some work at KTH, Lund University, Roskilde University and Uppsala University. The programme also includes collaborations with University of Copenhagen, the University of Edinburgh, and other institutions. Phase 1 (2012 to 2016) was funded by Mistra with 10 million SEK per year and co-funded by SLU with the same amount. Lantmännen also contributed financially with a sum of 50,000 SEK per year during the first phase. In phase 2 (2016-2020) Mistra and SLU continue their support, with additional funding from Lantmännen (800, 000 SEK), Graminor (770,000 SEK), and Lyckeby Starch AB (200,000 SEK) for the remaining four years. Many companies, agencies, and organisations also support the programme with their knowledge and advice.

We use the term "biotechnology" in a broad sense that includes (but is not limited to) the use of genomic tools, molecular markers, genetic modification, and gene editing as well as technologies for cell and tissue culture and for animal cloning.

RA1

DEVELOPMENT OF INNOVATIVE PLANT PRODUCTS USING MODERN BREEDING TOOLS

The major focus in this RA is the breeding for late blight resistance and altered starch composition in potato, and the development of field cress (*Lepidium campestre*) into a new oil and cover crop with several improved agronomic traits. The genetic improvement of target traits is carried out by using conventional breeding, genetic modification (GM), site-directed mutation including the new CRISPR/Cas9 technology, and other non-GM approaches. We analyse the characteristics and health aspects of the potato starch and the field cress seed oil of improved lines. Apart from the assumed reduced nutrient leaching through the domestication of the biennial, and potentially perennial, catch crop field cress, we address this issue through increasing plant nitrogen use efficiency in potato. We also work with improving leaf blotch resistance in barley.

RA2

REFINED TOOLS FOR MOLECULAR BREEDING

In RA2 the central focus is the improved use of molecular information in crops and livestock breeding by refining the tools for genomic and proteomic selection. Based on prior information on genetic variation and mathematical models of resource allocation we can differentiate among genomic regions in the selection process to improve feed efficiency in livestock. We will evaluate scenarios for genomic selection in crossbreeding in the context of current and potential future scenarios in livestock. We develop new diploid potato clones, implement genomic selection in existing potato breeding material, and investigate new ways to select for improved resistance against *F. graminearum* in oats. In our work on proteomics we search for peptides to be used as markers in potato breeding together with genomic information. The same approach is used in the work on bull fertility where we use our previously gathered information on a larger cohort of bulls.

RA3

SYNTHESIS AND SOCIAL ANALYSIS

It is not sufficient to produce new crop and livestock varieties and breeds, with all the desirable properties, without using them in a sustainable way. The new products also have to be introduced to, and accepted by, the food industry and consumers. This raises a wide range of issues: environmental effects, economic viability, legislation, attitudes and preferences among consumers and other stakeholders, as well as ethical considerations. This RA is devoted to analyses of these factors.

We perform field trials with the plants developed in RA1 in order to provide knowledge about agricultural properties and ecological consequences. The field trials also provide seeds and tubers for analyses of oil and starch quality (RA1), phenotypes for genomic analyses (RA2), and opportunities to communication activities that we use in studies of consumer attitudes.

Several studies focus on the GMO regulatory system in the EU and its effects on the use of biotechnology to make agriculture and food production more sustainable from an environmental, economic, and social point of view. We highlight ethical argumentation for and against different designs of the legislation. We use a hypothetical market introduction of genetically modified field cress as a case study, investigating scientific, regulatory, economic, and ethical barriers to its introduction, and arguments concerning naturalness, precaution, fairness, labelling, and consumer autonomy. We also perform a case study of the use of GM feed for animals in Swedish meat and dairy production, including a value chain analysis estimating the costs of segregation.

In a simulation study that includes genetic and economic investigations, as well as an ethical analysis, we analyse breeding programmes for GM livestock for food production.

We investigate how consumer attitudes to breeding biotechnologies are influenced by different types of information, and analyse farmers' perspectives on the use of such technologies.

“As a farmer, with both organic and conventional crops on my farm, I can clearly see that both ways of farming have their limitations”

– Peter Borring

Organic farming has much to gain from biotechnology

"And on the 8th day, God looked down on his planned paradise and said, 'I need a caretaker', so God made a farmer." This quote by Paul Harvey goes straight to the heart of many farmers around the world. At the same time we experience how agriculture is blamed for environmental pollution and climate-related problems. In a more and more urbanised world where less people come in contact with food production, and food production is becoming more of a global industry where factors such as weather, commodity prices, and currencies are affecting farmers globally, it is easy to blame a business with few people involved.

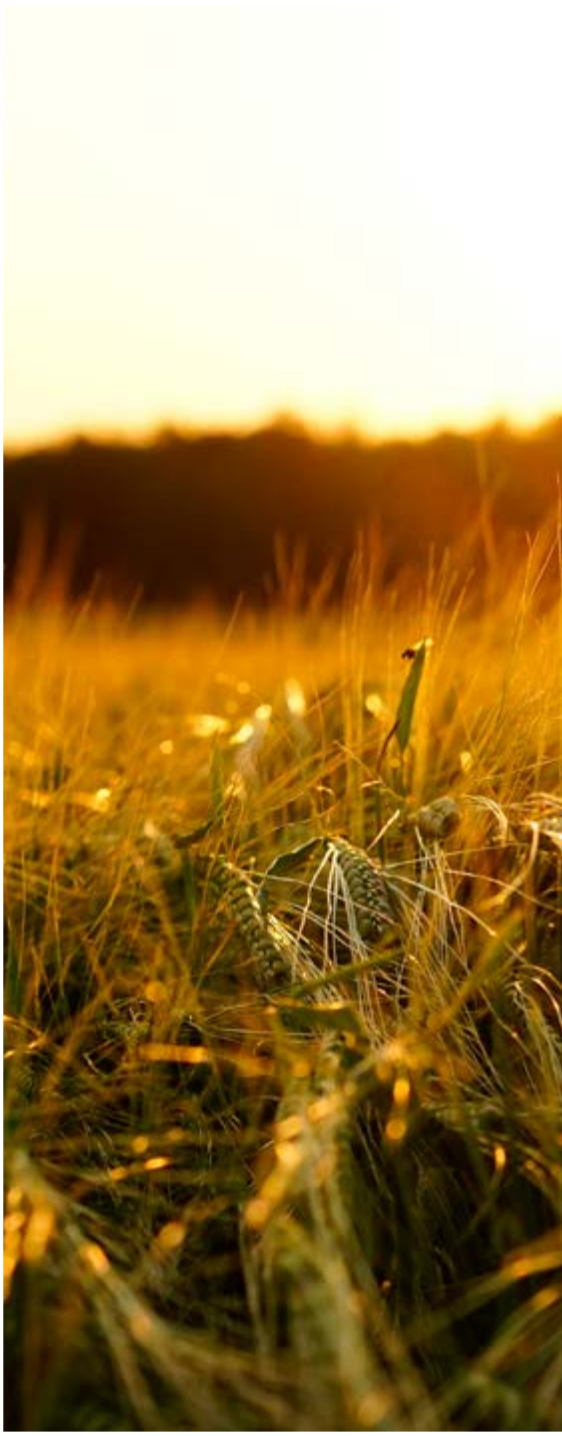
In response, more and more people, especially in developed countries with a high material standard, reflect on how their food is produced and what impact it has on nature. As a consequence we can see how sales and interest in vegetarian and vegan food is increasing, and sales of organic food hit records in for example Sweden, Germany, and the USA. The word *natural* is becoming the new religion among the informed and responsible consumers. Among some consumers, everything that can be connected to unnatural processes is rejected, for example fertilizers, chemicals and biotechnology. While many consumers make conscious choices in the grocery store, more food is consumed anonymously via restaurants, as well as through processed and pre-cooked food. The consumption of meat is increasing even in countries where many consumers claim that they reduce their meat consumption. The consumer is very complex in the way he or she lets price and convenience weigh more than the impact of the production on the environment and the climate. In future agriculture, we have to keep this inconsistent behaviour in mind when developing new ways of producing food.

The challenge is huge, considering that within the next 40 years to come, we have to produce the same amount of food as we have done in total during the last 8000 years. As a farmer, with both organic and conventional crops on my farm, I can clearly see that both ways of farming have their limitations. Conventional farming relies (mainly) on fertilizers and chemicals produced with fossil energy. Organic farming, on the other hand, is dependent on organic nutrients. If the system should rely only on nutrients that come from organic sources, the limited supply and the competition from weeds would undoubtedly lead to lower yields. High variations in yield would especially be seen in vulnerable crops like potato and rapeseed.

From my perspective on the puzzle of sustainable agriculture and food production, we should take the best parts of intensified farming, with high yields, and combine it with less input of fossil energy and chemicals, striving towards an increase in the circulation of nutrients. One of the most important pieces in the puzzle is the use of biotechnology for developing the traits we need in future crops. It is unfortunate that some of the proponents of organic farming are the ones who take most action against biotechnology, since organic farming would benefit the most from this technology. Scientist are working with perennial cereals, crops that can make use of nitrogen in the air, and crops that can make better use of organic nutrients, or that would even need less nutrients. These examples are low-hanging fruits in my organic fields.

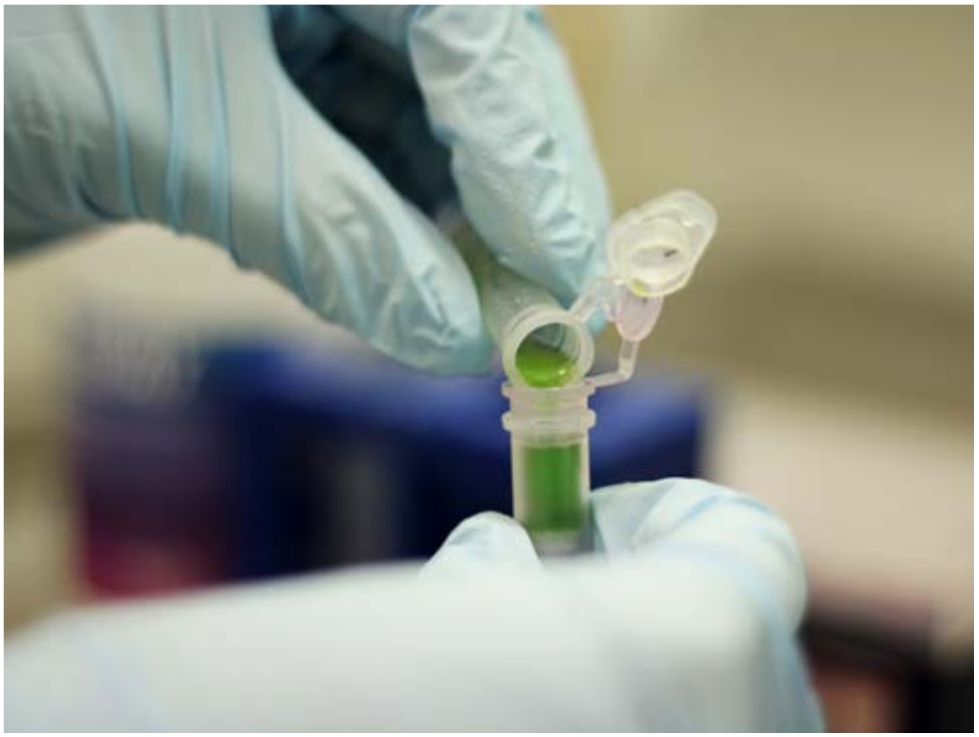
I think research programmes as Mistra Biotech are very important for developing future farming, not only for the pure knowledge and progress in science, but also for the contribution in letting the general public and our decision and policy makers know about the possibilities with biotechnology. Maybe, and hopefully, this will affect the debate in a more informed and balanced direction.

Peter Borring
Farmer with organic and conventional crop production



Mistra Biotech selections from 2016

In the following section our researchers present a selection of their latest results.



Policy context influences consumers' acceptance of GMO

We examined consumer behaviour in relation to a genetically modified (GM) product with direct tangible health benefits and indirect environmental benefits. Based on an experiment in Sweden, we studied how consumer behaviour depends on various policy regimes, and on actions taken by various actors in the food value chain. Respondents were randomly assigned to one of four policy scenarios, 1) a scenario where all activities related to production and commercialisation of GM food are completely prohibited, 2) GM is only used in research and development, 3) domestic production is prohibited but the import of GM foods is allowed, 4) full commercialization of GM products.

We show that policy context and stances taken by actors in the food chain had a decisive influence on consumers' acceptance decisions of GM food. Moreover, the effect was different for different segments of consumers. Support for the GM product increased if the food chain actors consistently endorsed it, and the rate of rejection increased if the actors did not endorse it. This confirms the supposition of increased consistency of consumer choice when the extent of similarity in food value chain stances is high. The chances of successfully introducing GM products could therefore increase if actors coordinate their stances. Further, our findings suggest that mandatory labelling actually reduce consumer rejection of GM foods.

In an additional experiment in Germany we looked at consumers' risk perceptions for four major risk sources: health, environment, socioeconomic, and ethical risks related to the use of genetic modification in the production. Randomly, the participants were faced with one of two policy scenarios; 1) research and development and 2) a scenario with full commercialization of GM products. Two types of products were included in the investigation: Bio-energy and food.

The consumers acted differently when exposed to the two different policy scenarios. We could also see that people perceived risks in different ways epending on the policy context. In particular, health risks were generally perceived lower for bio-energy than food when full commercialization was pursued. Furthermore, full commercialization of GM food raised concerns about personal health, whereas bio-energy production using GM crops was broadly related to higher levels of socioeconomic risks.

Finally, although the majority of consumers identified health risks as being most relevant, the consequences for the environment evoke the greatest degree of risk perception. Our findings lend support to the notion that the policy regime is the most important determinant for risk perception, followed by risk dimension, and trust in industry.

The results have been submitted to the scientific journals *European Review of Agricultural Economics* and the *International Journal of Consumer Studies* under the titles "Value chain actors' decisions and consumer's acceptance within the food biotechnology industry: Evidence from an artefactual field experiment" and "Debunking the myth of consumer rejection of green genetic engineering: empirical evidence from Germany".

Contact: *Ashkan Pakseresht, ashkan.pakseresht@slu.se*
Dept. of Economics, SLU

Our findings suggest that mandatory labelling actually reduces consumer rejection of GM foods.

After the oil has been pressed out from the field cress seeds you get something called a "seed cake" that could be used as a component in animal feed. Pigs find it a tasty feed ingredient and it does not seem to cause any harmful health effects.

Pigs eating field cress cake

Visually, it is impossible to see any difference between feeds with or without field cress cake, when the feed is pelleted. And the pigs do not seem to feel any difference in the taste either, at least they didn't prefer one feed over the other when served the different diets in this experiment.

In the beginning of 2016 eight growing pigs were fed with feed containing the so called cake from field cress. The cake is the pulp that is left over after we have pressed oil from the seeds. The pigs were kept in one of the stalls at the Centre for Veterinary Medicine and Animal Science in Ultuna, and for six weeks we gave them feed with zero, four, eight or twelve percent field cress cake.

From this study we can conclude that field cress cake is a tasty feed ingredient to pigs and it does not seem to cause any harmful health effects. However, analysis of the feeds and fecal samples from the pigs showed a higher proportion of indigestible fiber in the feed containing field cress cake, which resulted in a lower digestibility than the control diet without field cress cake. Strategies like dehulling of husk or supplementation of enzymes could probably improve this new potential feed component.

It would add an extra value to the future oil seed and catch crop field cress if also the cake from this plant could be used.

This study was performed as a Master thesis by Hagos Arefaine and is published at stud.epsilon.slu.se. The title is "Lepidium cake as a feed stuff to pigs". Emma Ivarsson at the Department of Animal Nutrition and Management was the supervisor.

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Dept. of Animal Nutrition and Management, SLU

Healthier oil and increased seed oil content in field cress

In the process of domesticating field cress (*Lepidium campestre*) we have increased the seed oil content, and changed the fatty acid composition of the oil in this potential oilseed crop. These improvements make the field cress oil suitable for food processing, especially for frying, and the plant produces more seed oil after specific genetic modifications.

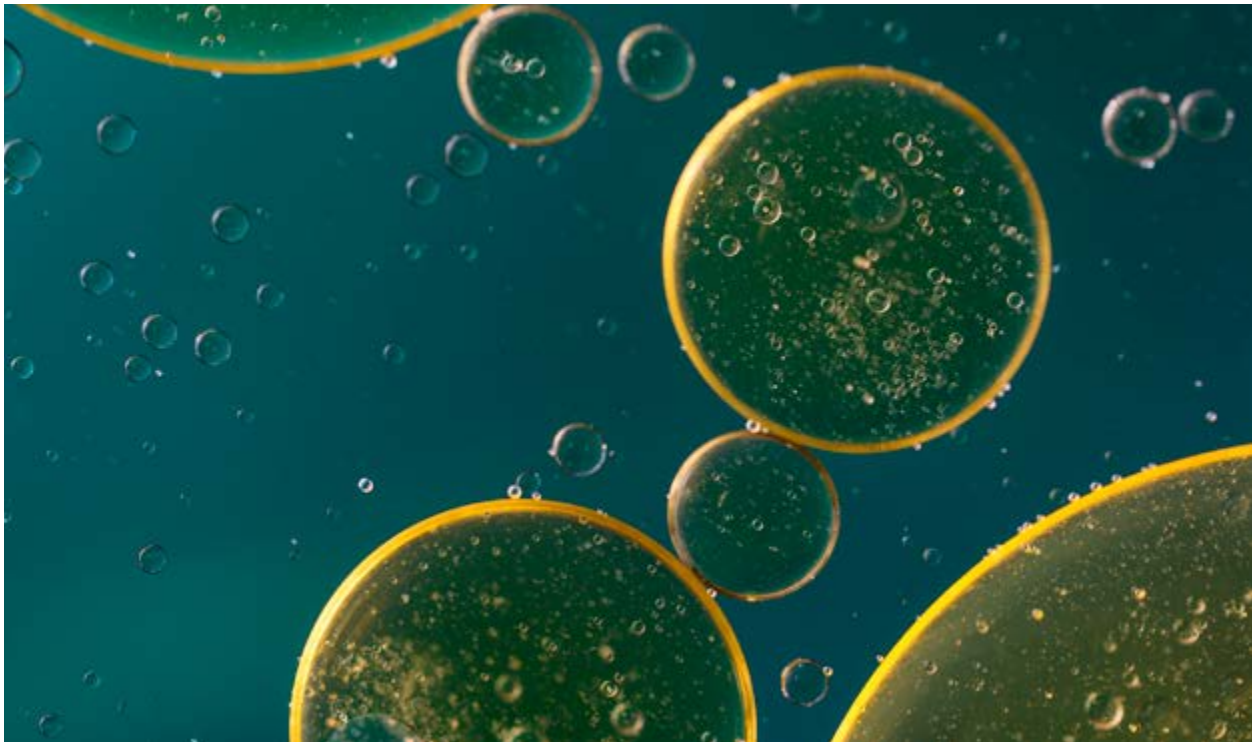
The seed oil in the modified field cress contains almost eight times more of the healthy oleic acid. Using the seed-specific RNAi silencing technique, we have decreased the expression of two genes that encode two enzymes regulating the fatty acid composition in this species. As a result the oleic acid level has increased from 11 to 84 percent, while the unhealthy erucic acid has been reduced from 20 percent down to 0.1 percent in the seed oil. Linolenic acid is also reduced, from 40 percent to 2.6 percent. Linolenic acid is a healthy polyunsaturated fatty acid, but it is unstable at high temperatures.

In addition, the total oil content has been elevated by inserting genes in such a way that they are only expressed in the seeds. The genes come from *Arabidopsis thaliana* and sugar beet, and through introducing them into field cress we got an increase in the oil content by up to 30 percent.

The increased oil level, and the changed oil composition, are important steps in the domestication process of field cress, since our aim is to develop this wild species into an economically viable crop for colder areas.

These results were published in the scientific journal *Plant Cell Reports* with the title "Significant increase of oleic acid level in the wild species *Lepidium campestre* through direct gene silencing" and in *Frontiers in Plant Science* with the title "Effects of overexpression of *WRI1* and hemoglobin genes on the seed oil content of *Lepidium campestre*", respectively.

Contact: *Li-Hua Zhu, li-hua.zhu@slu.se*
Dept. of Plant Breeding, SLU



By silencing two genes in field cress we managed to elevate the level of healty oleic fatty acid almost eight times, while reducing unhealthy erucic acid 200 times.

Pod shattering is a vital trait for seed dispersal in wild plants, but problematic in crops where you wish to harvest the seeds. The plant to the left have almost only empty pods, while the plant to the right is still holding on to its seeds after maturation.

Breeding and field evaluation of field cress

Keeping the seeds in the pods is a fundamental trait in agricultural crops, and hence a key breeding goal in the domestication of field cress (*Lepidium campestre*). Some of our best low pod-shattering lines germinated poorly due to seed dormancy. Hence, in the beginning of 2016, these lines with low pod shatter were crossed with lines that have excellent seed germination records, and most of the resulting hybrids showed excellent seed germination in the first two generations. The third generations are currently under vernalization in a cold-chamber. The plants will be transferred to an outdoor site during spring 2017 and evaluated for low pod shatter, seed yield, and other important traits. Hybrids that show both high seed germination and low pod shatter will be selected for further breeding as an important step towards stacking traits into common lines.

In parallel, we have started field testing of crossings of selected *Lepidium* lines, both within the species (intraspecific) and with other *Lepidium* species (interspecific crossing). During the summer of 2015, we selected 176 intraspecific and interspecific hybrid derived lines based on desired traits, such as high seed yield, low pod shatter, and synchronous maturation. After evaluating the performance of the 176 lines in terms of germination, growth vigour, weed competiveness, and flowering, 44 lines were selected for under-sowing in spring barley plots during the spring of 2016. The barley was harvested during the summer of 2016 whereas the field cress is currently over-wintering. Most of these selected lines are performing very well and the final results will be known during the summer 2017.

The 176 field cress lines were further evaluated for seed yield during May to August in 2016. The seed yield for lines that germinated well was estimated to vary from 1.8 to 4.5 tons per hectare. The yield was lower than expected mainly due to shortage of rain during the flowering stage of the plants. Based on the results, 24 lines were selected for multi-environment field trails at Lönnstorp, Lanna, Lännäs, and Umeå research stations.

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Strategies for table potato in Fennoscandia

The development of new potato cultivars has diminished in Norway and Sweden, and ceased altogether in Finland. We have taken a closer look at the potato breeding as well as the extent of cultivation, consumption and processing of potato in the Fennoscandian region (Sweden, Norway and Finland).

Talking about potato, Sweden, Norway and Finland have a lot in common. We prefer floury potatoes, such as King Edward, while elsewhere in Europe people prefer the firmer potatoes. We have the cold northern climate in common, with long days in the summer, and problems with the same kind of pathogens. On the other hand, we have no major problems with drought. Therefore, drought adaptation is not a highly prioritized breeding target for potato in this region.

The conclusions from this study are that the three countries should join hands and cooperate to develop better potato cultivars. Larger field trials, increased funding for long-term potato research, and a coordination of the breeding activities in Sweden, Norway and Finland – that is what we need to get a sustainable supply of adapted cultivars to potato farmers in the north.

Sweden, Norway and Finland should join hands and cooperate to develop better potato cultivars.

We need potato cultivars that do not have to be sprayed with fungicides. Most of the major cultivars we grow today are susceptible to late blight caused by the pathogen *Phytophthora infestans*. The spraying is bad for the environment and makes potato cultivation more expensive. Coming potato cultivars also need to be adapted to a future climate, which is predicted to become warmer and wetter in our region. Additionally, more pathogens and pests are expected to find their way to this region as the climate changes.

The Fennoscandian market is too small to motivate private sector seed companies to invest in potato breeding that matches the specific requirements of this region. Consequently, we rely on public investments to develop new cultivars, and such financial support must be maintained for a long time.

In our investigation, we found seven reasons for public investment in potato breeding in the Fennoscandian region:

1. National food self-sufficiency is an issue of high priority.
2. The environmental quality objectives *"A non-toxic environment"* and *"A varied agricultural landscape"*, adopted by the Swedish Parliament, will greatly benefit from new potato cultivars that are resistant to diseases, reducing the need for chemical crop protection.
3. The gross return on investment is generally very high for plant breeding.
4. The potato industry provides a large amount of employment opportunities.
5. The Fennoscandian region is well suited for potato cultivation. This crop has the highest fresh edible yield per hectare of all food crops in Sweden.
6. Existing cultivars need frequent fungicide treatments and are not adapted to the long days in the summer.
7. Potato is an essential component in the Swedish cuisine and the Swedish culture.

The study was published in the journal *Potato Research*, with the title "Overview and breeding strategies of table potato production in Sweden and the Fennoscandian region".

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Dept. of Plant Breeding, SLU

Gene-edited farm animals for food production

We have taken a first step into a deeper discussion about breeding genetically modified farm animals. Animal geneticists and ethicists have together discussed the biotechnical methods required for, and the different consequences of, genome editing and the application of these methods in livestock breeding programmes. We focused on two case studies; cattle with no horns and improved udder health in dairy cattle.

Dehorning of calves is used to avoid injuries to other animals and animal keepers, however it is an often criticized procedure. Selection for animals with no horns would therefore be preferable. In order to increase the frequency of cattle without horns in a population, genetic modification would open new opportunities.

The introduction of pathogen resistance in cattle could potentially decrease the incidences of udder infections and thereby improve animal welfare as well as decrease the use of antibiotics. We will discuss different ethical aspects of the cases including animal welfare and the potential effects on consumers among others.

Genetic modification (GM) is one of the central topics in Mistra Biotech, however, the main focus has been on the different applications in plant breeding and not so much on the use of GM in the breeding of livestock. During one of the Mistra Biotech workshops, external speakers talked about using the new genome editing techniques (for example CRISPR/Cas9) in farm animals. Those techniques are more likely than classic GM to be applied in farm animals since specificity and expected success rates are higher with genome editing. We aim to simulate a breeding programme using genome edited farm animals, followed by an ethical discussion around this topic as well.

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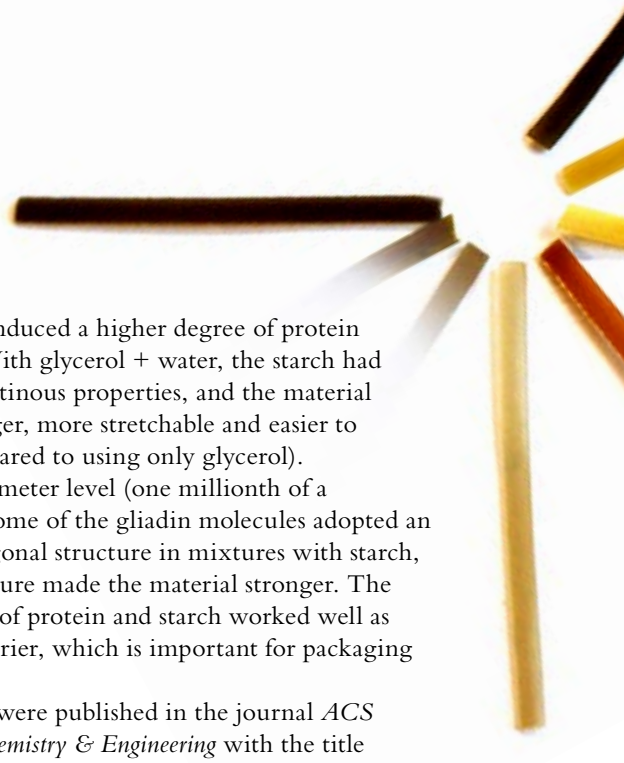
Plastics from potatoes



The "amylose potato" developed in Mistra Biotech has decreased amounts of two enzymes regulating the branching of starch molecules in potato. Thanks to this, the starch has the fiber-like properties that make it suitable as a component of a new plant based material.

In a collaborative project we have invented a new material made from the starch of genetically modified potato. It is a stretchable and strong composite material that can replace some of the plastics produced today. The produced material is completely biobased with the aim of being compostable. By tailoring mixtures of plant proteins and starch, one can design sustainable materials for various uses including packaging and plastic film.

The starch from our "amylose potato" was combined with proteins from wheat (gluten, gliadin, and glutenin), and glycerol or glycerol + water as plasticizers, at two different temperatures, 110 °C and 130 °C. In some cases, the material became relatively soft and flexible, and in other cases, stronger and less soft. The higher temperature induced a higher degree of protein cross-links. With glycerol + water, the starch had improved gelatinous properties, and the material became stronger, more stretchable and easier to process (compared to using only glycerol).

At the nanometer level (one millionth of a millimeter), some of the gliadin molecules adopted an unusual hexagonal structure in mixtures with starch, and this structure made the material stronger. The combinations of protein and starch worked well as an oxygen barrier, which is important for packaging materials.

The results were published in the journal *ACS Sustainable Chemistry & Engineering* with the title "Innovative gliadin/glutenin and modified potato starch green composites: chemistry, structure, and functionality induced by processing"

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Dept. of Plant Breeding, SLU

Improving plant nitrogen use efficiency

We have shown that the model plant *Arabidopsis thaliana* acquires organic nitrogen from the soil, despite that it is not forming mycorrhiza, and that the plant is dependent on a certain protein for this nitrogen uptake. The protein is an amino acid transporter, and we have performed a range of experiments on *Arabidopsis* mutants that are genetically modified so that they either lack the transporter or that they overproduce it.

When grown on agricultural soil, plants lacking the transporter had the lowest carbon/nitrogen ratios and the lowest abundance of nitrogen acquired from an organic source. The plants armed with more of the transporter had the highest carbon/nitrogen ratios and a higher abundance of nitrogen from an organic source. These are very promising results for us, since we want to enhance the nitrogen uptake efficiency in crops such as potato. The study was published in the journal *Plant, Cell & Environment* with the title "Amino acid transporter mutants of *Arabidopsis* provides evidence that a non-mycorrhizal plant acquires organic nitrogen from agricultural soil".

Arabidopsis is not a crop, but a model plant, often used to predict the effects of genetic modifications in agricultural plants. Now, an amino acid transporter from poplar has been expressed in potato by our Mistra Biotech colleagues at SLU in Alnarp and we hope to see the same increased nitrogen uptake in this crop species. The modified potato clones have been multiplied and we will evaluate their ability to take up organic nitrogen during 2017.

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Dept. of Forest Ecology and Management, SLU

How to label "natural" foods

A standard argument in the debate on biotechnology and food is that food produced using some kind of biotechnology (for instance genetic modification) is unnatural. Against this background we may understand demands for labelling food, for instance with claims such as 'all natural ingredients'. There is controversy on how to justify, design, and implement such labelling without misleading the consumer.

Naturalness is not one single concept, but several ones (polysemy). Furthermore, those concepts typically allow degrees, so that things can be more or less natural. This complexity should be reflected when food manufacturers label their products. However, there is no obvious way of presenting an aggregate measure of a particular food item's naturalness. One way to visualize this is to make a graphical presentation that contains several axes, with the degree of naturalness represented on each axis.

This is done in a recent scientific paper with the title "How to label 'natural' foods: A matter of complexity" in the journal *Food Ethics*. A diagram with more axes would probably be too complex to be practical. It would therefore be advisable to strike a balance between a label's being comprehensive and its being clear and easily recognizable. A way to solve this would be to analyze what combinations of naturalness axes are present in different food items. If some types of naturalness usually go together, the most common combinations could be represented by a small number of distinctive labels.

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Dept. of Crop Production Ecology, SLU

Are some food products more natural than others?

Incresed nitrogen use efficiancy in barley is predicted to reduce nitrogen leaching more in the northern than in the southern regions of Sweden.

Nitrogen efficient barley in model simulations

How can barley, potato, wheat, and other crops be tailored to take up nitrogen more efficiently? One strategy is to develop varieties with a denser and deeper root system. Another strategy is to use biotechnology to alter the activity of the enzymes that affect the uptake of nitrogen in plants.

Today there are no crop varieties modified to become more nitrogen efficient on the market. In the absence of commercial nitrogen efficient cultivars, we have simulated the cultivation of such crops.

In one project (Pernilla Tidåker et al.) have investigated the potential effects on yield, nitrogen leaching and carbon storage. We found that this kind of barley would reduce nitrogen leaching, and that it would also reduce the agricultural contribution to global warming thanks to (1) a higher yield, (2) an increased storage of carbon in the plants due to more biomass, and (3) a reduced emission of the greenhouse gas nitrous oxide. Using life cycle assessment combined with three simulation models based on previous observations of how plants affect and are affected by their environment we could estimate the effects. The simulations were based on conditions typical for barley cultivation in the south of Sweden and areas close to the lakes Hjälmaren and Mälaren. This study has been published in the *European Journal of Agronomy* with the title "Estimating the environmental footprint of barley with improved nitrogen uptake efficiency – a Swedish scenario study."

In addition we (Eckersten et al.) have investigated if the nitrogen efficient barley crop would be more useful in one region of Sweden than in another. We found that the potential of such a crop to reduce nitrogen leaching is higher in northern than southern regions. Its potential to increase the storage of organic carbon in the soil was assessed to be highest in central Sweden and lowest in the northern region, when studied on a hectare basis. However, on a regional basis the carbon storage effect would be higher in the north due to its larger area cropped with barley. These findings will be published in the journal *Acta Agriculturae Scandinavica*.

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Precautionary measures in need of an update

How should the precautionary principle be applied regarding genetically modified organisms (GMOs)? This is discussed in an article with the title "How to be cautious but open to learning: time to update biotechnology and GMO legislation", published in the scientific journal *Risk Analysis*.

The basic idea is that precautionary measures to protect human health and the environment should be science-based. This means that for precaution to be applied there should be scientifically credible evidence of a potential danger. On the one hand, this evidence need not be conclusive, i.e. precaution can be based on scientifically credible suspicions of danger. On the other hand, precaution should not be based on guesses that have no scientific support. Furthermore, precautionary measures should be updated as more scientific information becomes available. Decision makers should be prepared to strengthen the precautionary measures if the danger turns out to be greater than initially suspected, and to reduce or lift them, should the danger prove to be smaller. It is argued that most current legislation on agricultural biotechnology has not been scientifically updated in this respect for several decades. It therefore reflects outdated criteria for identifying products that can cause problems. Modern knowledge in genetics, plant biology, and ecology has provided us with much better criteria for identifying the potentially problematic breeding projects at which precautionary measures should be directed. Legislation on agricultural biotechnology should be scientifically updated so that it makes use of the scientific information that is available today.

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The ethical matrix

A common tool used for ethical evaluation of biotechnology is the ethical matrix. In a minor study, published in the book *Food futures: ethics, science and culture* with the title "The ethical matrix as a potential tool in public procurement of food", we endeavored to test this approach in a different context: ethical evaluation of public procurement of food. Small mixed groups of politicians and officials from Swedish municipalities applied the ethical matrix to some particular procurement issue. Whereas both groups were positive to the use of the tool, politicians were less positive regarding the usefulness of the matrix as a tool for political decision-making. Both groups emphasized that, on a municipality level, the most likely use of the matrix lies in the early stages of policy work to arrive at a common platform within working groups and also at a stage after decision-making in communication with citizens.

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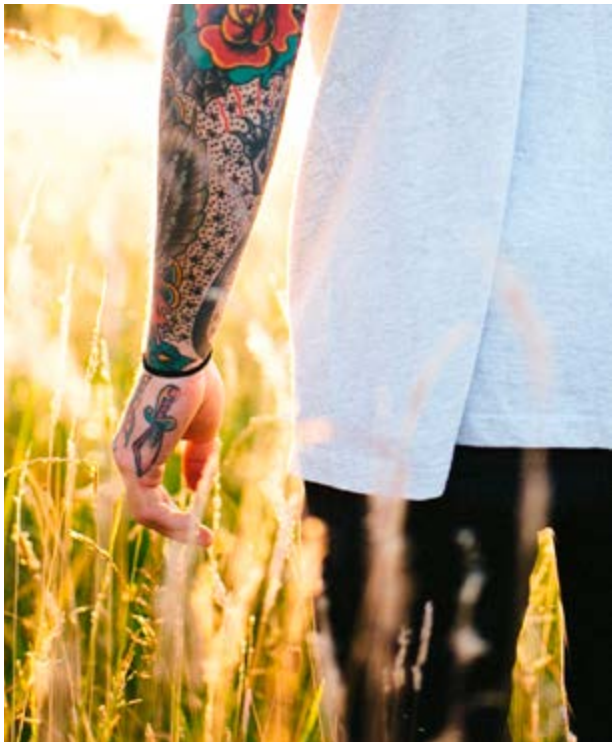

Precautionary measures should be strengthened if the danger turns out to be greater than initially suspected, and reduced if the danger prove to be smaller.

Genomic selection needs to be carefully assessed to meet specific requirements in both crop and livestock breeding programmes.

Goals and hurdles in genomic selection

We have summarized the goals and hurdles for a successful implementation of genomic selection in breeding programmes for rice, maize, wheat, barley, and forage grass, *i. e.* both annual and perennial crops. Further studies on methods and applications of genomic selection are required in order to allow highly accurate predictions across the variety of crop populations. Such studies should focus on population specific requirements (*e. g.* inbreeding or hybrid breeding). They should also include non-additive effects, especially genotype-by-environmental interactions. Each crop species has its own specific setting, and the application of strategies based on genomic selection is often far from easy.

A similar conclusion was drawn from a literature study of the application of genomic selection in different livestock populations. Genomic selection is already being used as a selection tool in dairy cattle, and the tool is also part of the planning of breeding programmes in many livestock populations (for example pig, beef cattle and chicken). Genomic selection needs to be carefully assessed to meet specific requirements in both crop and livestock breeding programmes.

Collaboration with the industry is needed in applications of genomic selection, since relevant findings can only come to use via the work of industry partners. Future studies should be more targeted towards breeding programmes and should be specific for different populations. Crop breeding can also be improved by further advancement of methods which include environmental factors. We finally conclude that an open exchange on the status of research results and achievements in breeding programmes is required to achieve significant successes.

The analyses were published in *Biotechnology and Genetic Engineering reviews* and *Frontiers in Genetics* with the titles "Goals and hurdles for a successful implementation of genomic selection in breeding programme for selected annual and perennial crops" and "Genomic selection needs to be carefully assessed to meet specific requirements in livestock breeding programs". Conclusions from our review papers will also be published in a chapter of the coming book *Population Genomics Concepts, Approaches and Applications* (Springer). It introduces methods and models, and gives a brief overview on the application of genomic prediction in livestock, companion animals, crops, trees and human populations.

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Biotechnology for environmental purposes

Unfortunately, agriculture has a large part in the environmental destruction caused by human beings. In the last 200 years, both the global area of cropland and that of pasture land have increased about six fold, leading to large losses in biodiversity. Agriculture has many other environmental problems, including those that pesticides, fertilizers, and irrigation give rise to. Therefore, all available means should be employed to improve the environmental sustainability of agriculture. Biotechnology is one of these means.

In a book chapter titled "Biotechnology for environmental purposes" (in Paul B. Thompson and David M. Kaplan *Encyclopedia of Food and Agricultural Ethics*, second edition, Springer 2016) Sven Ove Hansson briefly reviews some of the breeding projects that may have the potential to make a large difference in the environmental effects of agriculture, such as:

- *Pest resistant cultivars*. By developing such cultivars we can decrease the need for pesticides. This should be combined with other measures, such as crop rotation and mechanical and biological pest control.
- *Perennial crops*. It may be possible to replace some of the annual crops by perennial variants. This will reduce soil erosion and eutrophication.
- *Crops with improved uptake or use of nitrogen*. This can be an important means to reduce the need for fertilizers. The most radical proposal in this area is to make cereals able to fixate nitrogen from the atmosphere, just as legumes do. There are also other, less drastic ways to improve nitrogen efficiency.

These are just a couple of examples. Modern plant breeding has the potential to be one of the major instruments for achieving a more sustainable agriculture.

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There are many examples of breeding projects that may have the potential to make a large difference in the environmental effects of agriculture, for example resistance against potato blight.

The European regulatory framework on genetically modified organism fails to satisfy the criteria of legal certainty, non-discrimination, and flexibility.

Time for a new EU regulatory framework for GM crops?

We have analyzed the EU directive on the deliberate release into the environment of genetically modified organisms, based on five proposed criteria: legal certainty, non-discrimination, proportionality, flexibility, and inclusion of non-safety considerations.

Based on findings in this analysis we argue that the European regulatory framework fails to satisfy the criteria of legal certainty, non-discrimination, and flexibility. We also argue that there is room for questioning to what extent it satisfies the criterion of proportionality, and discuss two ways of reforming the present EU framework toward greater accommodation of the values expressed through these principles and criteria.

The first route towards a regulatory reform could be to retain a separate regulatory track for GM varieties (thus signaling that more thorough risk assessment might be required for GM varieties than for conventional varieties) but incorporate selected aspects of a product-based legislation into the legislation. This could for instance be done by reforming the risk assessment protocol presently in force so that it is based on the traits and gene functions, rather than the method used to introduce the trait.

The other way could be to abandon the present 'dual-track' system for crop introductions and instead introduce a new crop legislation based on sustainability criteria that apply to all varieties regardless of the breeding methods used. That is, instead of focusing on whether a crop has been developed through genetic modification or conventional breeding methods the legislation would depart from the values that are central to achieving a sustainable development within plant breeding. This is a solution in line with the non-discrimination principle.

Both options, in different ways, constitute a regulatory shift for GM varieties within the EU. The reason for doing this analysis is that in recent years, the EU legislation on genetically modified crops has come under severe criticism. Among the common arguments are that the present legislation is inconsistent, disproportionate, obsolete from a scientific point of view, and vague in terms of its scope. The study has been submitted to *Journal of Agricultural and Environmental Ethics*.

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Department of Law, Uppsala University


“Working in Mistra Biotech gives me a chance to connect with researchers outside my field and gives me great opportunities for presenting my own research”
– Catja Selga

Searching for the keys to improved potato cultivars

Catja Selga has just started her PhD at SLU in Alnarp. Her work is part of the research that strives to develop high yielding potatoes that are resistant against the pathogen causing late blight. Catja became interested in genetics during her first year as a student at Lund University.

– At first I studied ecology, but quite soon I changed track and went into genetics, she says.

The possibility to work with plant breeding caught her attention when she took some extra courses at SLU during her last Master year at Lund University, and she feels at home in applied research.

– I have always known that I want to pursue a career that will benefit the public, says Catja.

Finding ways to prevent production losses and the need for pesticides due to *Phythophtora infestans*, the pathogen causing late blight, would certainly benefit the public. Finding high yielding crop cultivars with high resistance to pathogens is vital for our food production. Potato is one of the world's staple food crops, and late blight is the most devastating potato disease. Potato breeding is a time and labor intensive project, due to the multiple cycles of screening for traits. Catja investigates how specific traits in potato plants are connected to genetic variation in order to develop knowledge useful for genomic selection.

– Every plant in my breeding scheme gets a score for these phenotypic traits and with this result I can estimate breeding values for each trait in each individual plant. The breeding values are employed when picking parents for the new crosses, and when selecting which crosses should be kept in the breeding programme. My project runs alongside SLU's potato breeding programme, which gives me a great opportunity to learn about conventional potato breeding techniques. The goal of my project is to obtain a high yielding food potato that has high resistance to late blight.

Genomic selection is a new and promising breeding tool which offers off-season selections that can be conducted without long periods of labor intensive selection in fields or greenhouses. Genomic selection has a high potential of reducing the time and money spent on obtaining new crop cultivars, especially when selecting for traits affected by many genes.

In her project Catja collaborates with several researchers within the programme.

– Working in Mistra Biotech gives me a chance to connect with researchers outside my field and gives me great opportunities for presenting my own research. I think that it is beneficial in research in general to increase crossdisciplinary collaborations. The Mistra programme is an excellent growing ground for these types of collaborations.

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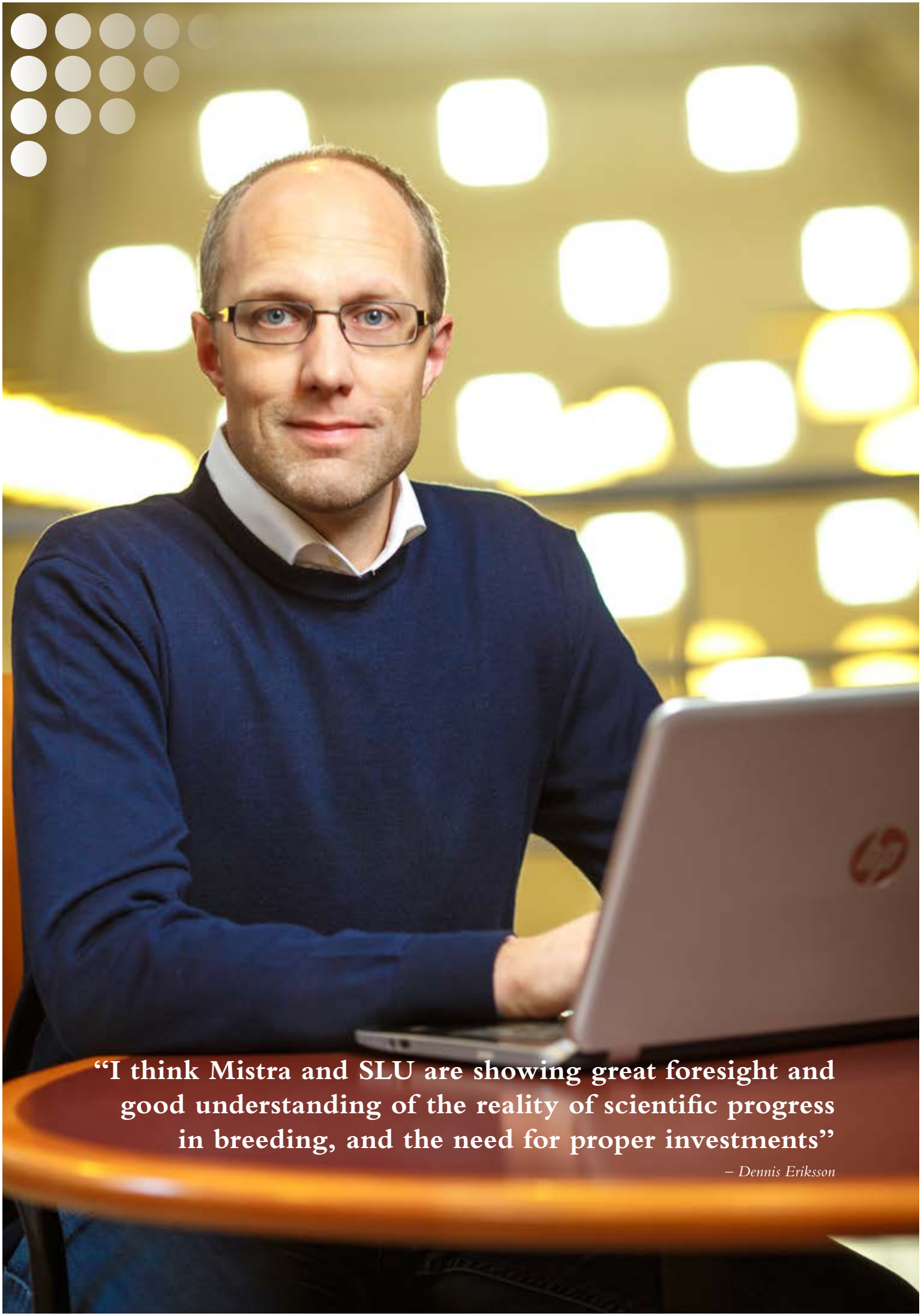

“I think Mistra and SLU are showing great foresight and good understanding of the reality of scientific progress in breeding, and the need for proper investments”

– Dennis Eriksson

A networking plant researcher with a focus on policy questions

Dennis Eriksson grew up on the countryside in southern Sweden and moved to Lund to study biology. His studies took him to Singapore for his thesis work, to the International Potato Center in Peru for an internship, and to Copenhagen as a Postdoc after his PhD studies at SLU in Alnarp. Dennis also spent nine months at EPSO (European Plant Science Organisation) in Brussels as a Mistra fellow*. It was in Singapore and Peru that he got his first hands-on experience with genetically modified plants, and now he is looking into various perspectives on the EU regulatory system for different plant breeding techniques.

Current developments particularly in genome editing greatly facilitate and enhance the work of researchers and breeders, and there are already numerous potential applications under development or in the pipeline to the market. However, in the EU, progress is threatened to be stalled due to the uncertain regulatory situation.

– I am looking at a combination of technical and legal perspectives of old and new mutation techniques in breeding, particularly how the current EU directives treat or *should* treat each technique. Similarly, I am looking at the implementation of current legislation on some of the new breeding techniques, *e.g.* genome editing.

Another issue Dennis is focusing on is a comparative analysis of existing and theoretical or proposed regulatory systems for plant breeding techniques; this includes a comparative overview of systems in various countries/regions as well as putting proposed frameworks (from the scientific literature) to the test through case studies.

– I have a large network and I am trying to adopt a multidisciplinary approach in my work, incorporating ideas and comments from colleagues from the legal, social, economic, and philosophic disciplines, as well as from various stakeholders such as companies, farmer organisations, NGO's, and policy makers.

While working in Brussels he built an international and multidisciplinary network of people working with plant biotech regulatory issues.

– My goal is to turn this network into some kind of permanent structure providing a forum for discussions and a platform for collaborative research and output. I believe it may be of great value to Mistra Biotech, from which there are nine researchers in the mentioned network, to link the work being carried out in the programme to a larger international context of professionals working with plant biotech regulations.

– It is a very rewarding experience to take part in a multidisciplinary programme as Mistra Biotech. In funding the programme, I think Mistra and SLU are showing great foresight and good understanding of the reality of scientific progress in breeding, and the need for proper investments in order to face societal and environmental challenges in Sweden and beyond. I am very happy to be part of it, and I do hope to be able to contribute to the progress and the goals of Mistra Biotech.

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** The Mistra Fellow Programme gives young researchers in Mistra programmes the opportunity to spend up to a year at think tanks or international organizations to get a deeper understanding of European and international policy processes.*

Board Members

Name	Affiliation
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Dirk Jan de Koning	Animal Breeding and Genetics, SLU	Project Leader RA2
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Per-Erik Holmlund	Crop Production Ecology, SLU	Financial Administration
Anna Lehrman	Crop Production Ecology, SLU	Deputy Programme Director, Communications Officer

Researchers

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Camila Cambui	Genetics and Plant Physiology, SLU
Carl Johan Lagerkvist	Economics, SLU
Carolin Menzel	Food Science, SLU
Catja Selga	Plant Breeding, SLU
Cecilia Gustafsson	Plant Breeding, SLU
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Emma Ivarsson	Animal Nutrition and Management, SLU
Emma Hansson	Economics, SLU
Erik Alexandersson	Plant Protection Biology, SLU
Erik Andreasson	Plant Protection Biology, SLU
Fernando Lopes Pinto	Animal Breeding and Genetics, SLU
Fredrik Levander	Immunotechnology, Lund University
Fredrik Reslow	Plant Breeding, SLU
Hagos Arefaine Mesele	Animal Nutrition and Management, SLU
Helena Röcklinsberg	Animal Environment and Health, SLU
Henrik Eckersten	Crop Production Ecology, SLU
Henrik Svennerstam	Forest Genetics and Plant Physiology, SLU

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Håkan Marstorp	Soil and Environment, SLU
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Inger Åhman	Plant Breeding, SLU
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Roger Andersson	Food Science/Molecular Science, SLU
Sebastian Hess	Dairy and Food Industry Economics , Kiel University
Selvaraju Kanagarajan	Plant Breeding, SLU
Sevasti Chatzopoulou	Society and Globalisation, Roskilde University
Shyam Kumar Basnet	Economics, SLU
Sung-Yong Kim	Plant Breeding, SLU
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Ulrika Ganeteg	Forest Genetics and Plant Physiology, SLU
Xue Zhao	Food Science/Molecular Science, SLU
Zeratsion Abera Desta	Plant Breeding, SLU

** Royal Institute of Technology (KTH)*

Guided tour in the potato field trial outside Borgeby. Mistra Biotech organizes guided tours in different field trials every year. The tours are open for the public.

Mariette Andersson, Carl Johan Lagerkvist, and Inger Åhman gave presentations at the Mistra Biotech seminar "Framtidens mat i nordligt klimat - klarar vi oss utan inhemsk växtförädling?" at "Almedalsveckan" in Visby.

Activities

9-13/1 Dirk-Jan de Koning gave a talk and presented a poster on “RAD sequencing of diverse accessions of *Lepidium campestre*, a target species for domestication as a novel oil crop” at the Plant & Animal Genome Conference XXIV in San Diego.

15/2 Per Sandin gave a talk “Are we done with debunking? Using the category of nature in technology and environmental philosophy” at the First Annual Bovay Workshop on Engineering and Applied Ethics, Texas A&M University.

2/3, Nawaporn Onkokesung talked about “Genome-editing technologies: Prospective novel techniques for agronomical crop breeding” at the Annual Plant Biotech Denmark meeting at the University of Copenhagen.

17/3 Rodomiro Ortiz provided the invited talk “Another Inconvenient Thruth: Plant Genetic Engineering as a Means to Improve Food Security. Activities Related to Africa.” at Modern Genteknik vid Livsmedelprouduktion in Uppsala.

18/3 Rodomiro Ortiz gave invited talk “Plant Breeding towards a Future Sustainable Farming: SLU Potatisförädling” at Stiftens Stärkelsen Forskning & Utveckling Inpirationsseminarium in Lyckeby Culinar AB, Fjälkinge.

21/3 Per Sandin participated at the workshop “Vad är ett hållbart jordbruk i Norrbotten?”, Länsstyrelsen i Norrbotten, Luleå.

11/4 Mistra Biotech symposium at Royal Swedish Academy of Agriculture and Forestry (KSLA), Stockholm: “Bioteknik för hållbarhet i jordbruket”.

28/4 Mariette Andersson gave a presentation “CRISPR/Cas9 - nytt verktyg för växtförädling med precision” for Livsmedelskollegiet in Lund.

10/5 Elisabeth Jonas gave her Docent lecture ”Kan vi överföra forskning inom molekylär och kvantitativ genetik till tillämpade avelsprogram för att förbättra selektion i framtiden? ” at SLU, Ultuna.

11/5 Dennis Eriksson gave a presentation ”Regulatory challenges in the EU for genome editing in crops” at a seminar with the SLU Plant Breeding Platform, Alnarp.

7/6 Carl Johan Lagerkvist and Per Sandin gave two presentations at the seminar “Femtio nyanser av grönt – om KSLA:s dialogprojekt ‘Biotekniken i växtodlingen’” KSLA, Stockholm.

7/6 Rodomiro Ortiz gave invited lecture on “Genomic Selection for Plant Improvement” at the Annual Meeting of the Plant Genetic and Biotechnology Network: “New Breeding Techniques; Genome Editing, Cisgenesis and Genomic Selection” in Università Cattolica del Sacro Cuore, Piacenza, Italy.

13/6 Rodomiro Ortiz gave talk on “Plant Genetic Engineering for Improving Food & Nutrition Security, and Promoting Sustainable Agriculture” at Symposium “What role can genetic engineering play worldwide in improving food & nutrition security and promoting sustainable agriculture?” in WUR, Wageningen, The Netherlands.

20/6 Student Hagos Arefaine Mesele presented his master thesis “Lepidium cake as a feedstuff to pigs” at SLU, Ultuna.

29-30/6 Lisa Beste, Erik Andreasson and Erik Alexandersson arranged a trip in the Mistra Biotech potato field in Borgeby, for visitors at the fair Borgeby fältdagar.

1/7 Rodomiro Ortiz gave invited closing keynote on “El Mejoramiento de los Cultivos más Allá de la Era de las Ómicas” at REDBIO IX, Lima, Perú.

4/7 Dennis Eriksson took the initiative to, and coordinated, a letter from European research organisations to call upon the European Parliament to encourage society to respect independent science advice and to condemn physical attacks on scientists. This was a reaction to the attack on EFSA June 7.

5-8/7 Li-Hua Zhu, as one of the members in the scientific committee, participated in the 22th International Symposium on Plant Lipids (ISPL), which was hold in Göttingen, Germany.

6/7 Mistra Biotech seminar ”Framtidens mat i nordligt klimat - klarar vi oss utan inhemsk växtförädling?” at Almedalsveckan, Visby. Presentations and contributions by Inger Åhman, Mariette Andersson, Carl Johan Lagerkvist and Lisa Beste.

20/8 Anna Lehrman, Dirk-Jan de Koning and Lisa Beste represented Mistra Biotech in the "forskartälten" at the event "Matologi - kunskap för hälsa och hållbarhet" in Stockholm, organized by SLU. Anna Lehrman also gave a presentation "GMO - vad är grejen?" and Per Sandin Talked about "Är vi vad vi äter?" at the event.

24/8 A group from the strategic department at Lantmännen visited SLU and Anna Lehrman gave a presentation about GMO and Mistra Biotech.

25/8 Dennis Eriksson gave a presentation "The legal certainty in the EU for applications of NPBTs" at the ELLS MSc summer course "New plant breeding technologies" at the University of Copenhagen.

26/8 Erik Alexandersson gave a presentation on "The Mistra Biotech Research Program and Examples from GM Potato Field Trials" at the ELLS MSc summer course " New plant breeding technologies" at the University of Copenhagen.

26/8 Mistra Biotech open field: Erik Andreasson (supported by Anna Lehrman) guided the participants through the potato field trials at Borgeby.

4-8/9 Erik Andreasson gave a talk on "Potato proteomics towards pathogen resistance" at the 2nd International plant proteomics organization world congress in Bratislava, Slovakia.

6/9 Dirk-Jan de Koning was a panel member at the first NIB Specialist Meeting: Genome Editing and the Future of Farming in Edinburgh, Scotland.

23-28/9 Rodomiro Ortiz was the course leader and co-organizer of the 2nd Workshop on "Genomic Selection in Plant Breeding: from Theory to Practice" held in Rabat, Morocco.

29/9 Rodomiro Ortiz gave an invited talk on "Genomic Prediction in Plant Breeding: Beyond the State of the Art" at 1st International Symposium on Genomic Selection for Crop Breeding in Rabat, Morocco.

20/10 Rodomiro Ortiz was invited as a speaker to deliver talk on "India GMO Development" at "Modern Genteknik vid Livsmedelprouduktion" held in Uppsala.

4/10 Elisabet Jonas gave a lecture on breeding programs for genetically modified farm animals as part of a course in the Animal Science program, at SLU.

6/10 Dennis Eriksson gave a presentation "Regulation in the European Union for genome-edited plants" and Mariette Andersson talked about "CRISPR/Cas9 takes several bites in the potato genome" at the PlantLink Day, Lund.

26/10 Per Sandin gave a presentation "Ansvaret för framtiden: Mitt, ditt, allas eller ingens?" at Framtidens Lantbruk's conference "Lantbruk 1,5°" in Stockholm.

28/9-1/10 Helena Röcklinsberg gave a presentation about "Facilitating decision making in public procurement of food through digital tools" and Per Sandin gave a presentation about "The ethical matrix as a potential tool in public procurement of food" at the 13th Congress for the European Society for Agricultural and Food Ethics (EurSafe), Porto, Portugal, 28 sep-1 oktober. Per Sandin also participated as a commentator on a symposium about Paub B. Thompsons book "From Field to Fork: Food Ethics for Everyone" at the same event.

7/11 Mariette gave a talk "Växtförädling för bättre hälsa och miljö- biotronen en viktig resurs i ett föränderligt klimat" at the inauguration of the Biotron at SLU, Alnarp.

16/11 Mariette Andersson held a course on mutagenensis at SLU, Alnarp "Potato and CRISPR-Cas9 – Mutual love".

9-13/12 Torgny Näsholm was invited speaker giving the talk "Plant Organic Nitrogen Nutrition" at the International workshop on Nutrient Stewardship and Next Generation Fertilisers. Heron Island, Australia.

19/12 Susanne Eriksson gave a lecture "Kloning och GM-djur" as part of a course in the Ethology and Animal welfare program, at SLU.

During Borgeby Fältdagar the visitors had the opportunity to join guided tours in the field trials where we grow the potato bred for resistance against Phytophthora infestans.

Hagos Arefaine Mesele presenting his Master Thesis "Lepidium cake as a feed stuff to pigs".

Interactions and collaborations between researchers in different scientific areas form an important part of Mistra Biotech. The annual programme meeting is one occasion when knowledege is shared between natural and social scientists.

Mistra Biotech in the media

NEWSPAPERS/WEB

31/1 Veterinärer kräver krafttag mot hundavel, Helsingborgs Dagblad

2/3 Per Sandin: Hans Ruins bild stämmer inte med verkligheten, Dagens Nyheter

17/5 Per Sandin: Naturligt eller inte – från filosofi till corn flakes, Curie

12/6 20 år efter Dolly – nu kan du klona jycken, Aftonbladet Plus

4/7 Nya tekniker för nya möjligheter, Svenska Livsmedel

22/8 Genmodifierad potatis banar väg för miljövänlig och effektiv odling, Sydsvenskan

17/9 Stort framsteg med genteknik, ATL

5/10 På spaning efter framtidens kväveeffektiva korn, Forskning.se

6/10 Dennis Eriksson bytte labbet mot skrivbordet, Mistra

14/10 Ny genmodifierad potatis får odlas utan tillstånd, Svenska Måltider

14/10 Första grödan med gensaxen, Ny Teknik

16/10 Svenska forskare skräddarsyr ny potatis, ATL

17/10 Sveriges nyaste potatis, Jordbruksaktuellt

28/10 Mindre miljöpåverkan från morgondagens kornsorter? Jordbruksaktuellt

3/11 Ett steg närmare nyttig olja från Norrland, Livsmedel.se and Forskning.se

3/11 Superolja från Norrland finns snart i hyllorna, Dagens Hälsa

10/11 Studie i Mistra Biotech visar vikten av kväveeffektiva grödor, Mistra

14/11 SLU vill se hållbar potatisodling, ATL

21/11 SLU vill odla mänskligt blod i GMO-växter, Land Lantbruk

21/11 GMO-plantan kan ge blod, Jordbruksaktuellt

21/11 Mänskligt blod odlas i plantor, Metro, Dagens Medicin, Helsingborgs Dagblad, Smålandsposten, Norrbottenskuriren, Piteåtidningen, and DN

21/11 Odlar konstgjort blod i tobaksplantor, Vårdfokus

21/11 Så odlas mänskligt blod, Netdoktor.se

29/11 Ny potatissort ger miljövänlig plast Forskning.se. Also reported by Livsmedel.se, and ProduktAktuellt

4/12 Genmodifierad potatis ger bioplast, ATL

6/12 Gensaxen fixar den perfekta stärkelsen, Naturvetaren

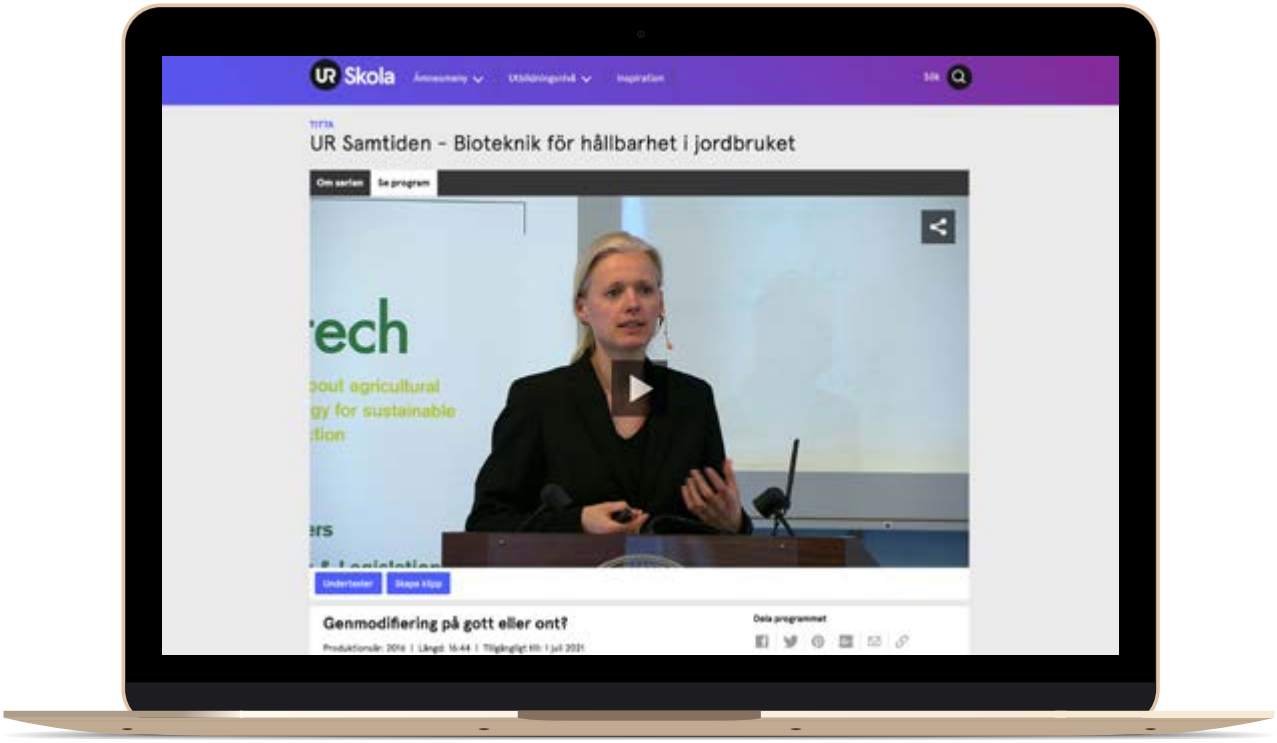
7/12 Hon gör vegetariskt blod av tobak i Alnarp, Sydsvenskan

1/12 Potatisen förenar grannländer, Jordbruksaktuellt

6/12 Gensaxen fixar den perfekta stärkelsen, Naturvetare

nr 4/2016 Integrerad bladmögelstrategi allt närmare, Viola Potatis

The newspaper Sydsvenskan wrote a feature article about our potato research.



Karin Edvardsson Björnberg was one of several presenters during the Mistra Biotech symposium "Bioteknik för hållbarhet i jordbruket" at the Royal Swedish Academy of Agriculture and Forestry (KSLA). The event was filmed by Utbildningsradion (UR) and the presentations are available on their homepage.

RADIO/TV

25/3 Specialdesignade barn och mammutar i blåbärsskogen, Sveriges Radio

15/5 Sten Stymne vill rädda landsbygden genom att göra åkern till kemifabrik, Sveriges Radio

25/5 UR Samtiden - Bioteknik för hållbarhet i jordbruket:

- Fältkrassing framtidens oljeväxt
- Klimatsmarta spannmål
- Bioteknik i matproduktion
- Genmodifierad GI-potatis
- Genmodifiering på gott eller ont?

26/5 Förälskad i en knöl, Sveriges Radio

16/7 Dennis Eriksson talks about GMOs in the radio programme Morgonpasset i P3, Sveriges Radio

14/10 Genklippt knöl kan ersätta förbjuden gmo-potatis Vetenskapsradion, Sveriges Radio

18/10 Här tas en skräddarsydd potatis fram, SVT Nyheter

21/11 Hon gör vegetariskt blod av tobak, SVT Nyheter (also Vetandets värld)

21/11 Här odlas mänskligt blod i tobak, Sveriges Radio

The Swedish public radio reported about Mariette Andersson's research on the use of CRISPR/cas9 technology on potato.

Publications

Alexandersson, E., Mulugeta, T., Lankinen, Å., Liljeroth, E., & Andreasson, E. 2016. Plant resistance inducers against pathogens in Solanaceae species - from molecular mechanisms to field application. *International Journal of Molecular Sciences* 17: 1673

Andersson, M., Turesson, H., Nicolia, A., Fält, A-S., Samuelsson, M., & Hofvander, P. 2016. Efficient targeted multiallelic mutagenesis in tetraploid potato (*Solanum tuberosum*) by transient CRISPR-Cas9 expression in protoplasts. *Plant Cell Reports* 36: 117

Arefaine, H. 2016. Lepidium cake as a feed stuff to pigs. Master Thesis, SLU

Bassi, F., Bentley, A., Charmet, G., Ortiz, R & Crossa, J. 2016. Breeding schemes for the implementation of genomic selection in wheat (*Triticum* spp.). *Plant Science* 242: 23-36

Brunius, C., Moula, P., & Sandin, P. 2016. The ethical matrix as a potential tool in public procurement of food, in *Food futures: Ethics, science and culture* (pp. 395-398). Wageningen Academic Publishers

Chawade, A., Alexandersson, E., Bengtsson, T., Andreasson, E., & Levander, F. 2016. Targeted proteomics approach for precision plant breeding. *Journal of Proteome Research* 15: 638-646

de Koning, D. J. 2016. Meuwissen et al. on Genomic Selection. *Genetics* 203: 5-7

Eriksson, D., Carlson-Nilsson, U., Ortíz, R., & Andreasson, E. 2016. Overview and breeding strategies of table potato production in Sweden and the Fennoscandian region. Potato Research 59: 279-294

Eriksson, D. Fact sheets on new breeding technologies, EPSO Agricultural Technologies Working Group

Ganeteg, U., Ahmad, I., Jämtgård, S., Aguetoni-Cambui, C., Inselsbacher, E., Svennerstam, H., Schmidt, S., & Näsholm, T. 2016. Amino acid transporter mutants of Arabidopsis provides evidence that a non-mycorrhizal plant acquires organic nitrogen from agricultural soil. *Plant, Cell & Environment* 40: 413-423

Geleta, M, & Ortiz, R. 2016. Molecular and genomic tools provide insights on crop domestication and evolution. In Sparks, D. L. (ed.) *Advances in Agronomy* 135: 181-223

Gjerris, M., Gamborg, C., & Röcklinsberg, H. 2016. Ethical aspects of insect production for food and feed. *Journal of Insects as Food and Feed* 2: 101-110

Hansson, S.O. 2016. Biotechnology for environmental purposes, in P.B. Thompson, D.M. Kaplan (eds.), *Encyclopedia of Food and Agricultural Ethics* (pp. 1-7)

Hansson, S.O. 2016. How to be cautious but open to learning: Time to update biotechnology and GMO legislation. *Risk Analysis* 36: 1513-1517

Ivarson, E. 2016. Development of *Lepidium campestre* into a new oil and catch crop. (Doctoral thesis)

Ivarson, E., Ahlman A., Lager I., & Zhu, L-H. 2016. Significant increase of oleic acid level in the wild species *Lepidium campestre* through direct gene silencing, *Plant Cell Reports* 35: 2055-2063

Ivarson, E., Leiva Eriksson, N., Ahlman, A., Kanagarajan, S., Bülow, L., & Zhu, L. H. 2016. Effects of overexpression of WRI1 and hemoglobin genes on the seed oil content of *Lepidium campestre*. *Frontiers in Plant Science* 7: 2032

Jonas, E., & de Koning, D.J. 2016. Goals and hurdles for a successful implementation of genomic selection in breeding programme for selected annual and perennial crops. *Biotechnology and Genetic Engineering Reviews* 1-25

Mao, X., Johansson, A. M., Sahana, G., Guldbrandtsen, B., & De Koning, D. J. 2016. Short communication: Imputation of markers on the bovine X chromosome. *Journal of Dairy Science* 99: 7313-7318

Muneer, F., Andersson, M., Koch, K., Hedenqvist, M. S., Gällstedt, M., Plivelic, T. S., Menzel, C., Rhazi, L., & Kuktaite, R. 2016. Innovative gliadin/glutenin and modified potato starch green composites: Chemistry, structure and functionality induced by processing. *ACS Sustainable Chemistry & Engineering* 4: 6332-6343

Rönnegård, L., McFarlane, S. E., Husby, A., Kawakami, T., Ellegren, H., & Qvarnström, A. 2016. Increasing the power of genome wide association studies in natural populations using repeated measures – evaluation and implementation. *Methods in Ecology and Evolution* 7: 759-877

Sahana, G., Iso-Touru, T., Wu, X., Nielsen, U. S., Koning, D. J., Lund, M. S., Vilkki, J., & Guldbrandtsen, B. 2016. A 0.5-Mbp deletion on bovine chromosome 23 is a strong candidate for stillbirth in Nordic Red cattle. *Genetics Selection Evolution* 48: 1

Sprink, T., Eriksson, D., Schiemann, J., & Hartung, F. 2016. Regulatory hurdles for genome editing: process- vs. product-based approaches in different regulatory contexts. *Plant Cell Reports* 35: 1493-1506

Tidåker, P., Bergkvist, G., Bolinder, M., Eckersten, H., Johnsson, H., Kätterer, T., & Weih, M. 2016. Estimating the environmental footprint of barley with improved nitrogen uptake efficiency – a Swedish scenario study. *European Journal of Agronomy* 80: 45-54

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