Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Mistra Biotech
Annual Report 2014

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Contents

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MISTRA
The Swedish Foundation for Strategic Environmental Research

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

It is always fascinating to listen to plant breeders when they talk about possible future crop varieties. Unfortunately, and despite many improvements, agriculture still has significant negative impacts on the environment. But there are several ways to improve this situation. Researchers at Mistra Biotech are developing new plant traits that can increase the nitrogen uptake and the efficiency of nitrogen use of important crops. If successful, this research will make it possible to reduce the use of fertilizers and thereby reduce nitrogen leakage into rivers and lakes. Other researchers are looking for new ways to reduce the need for tillage, which is a major cause of nitrogen leakage and a large contributor to greenhouse gas emissions. There are also interesting projects aiming at pathogen resistance that would decrease the need for pesticides, and drought tolerance that would diminish the need for irrigation. The total picture is fascinating, and the hope is that agriculture in the near future will be much more sustainable than it is today.

In addition to environmental concerns, climate change also makes it necessary to develop new crop varieties that are suitable for a warmer and more variable climate. This is a complex task because several properties of the plants are affected, but not much has yet been done to solve this problem.

All of this is challenging research. Even with the best of technologies, it takes many years to develop new crops that are ready to be used in practice. Despite the importance of making agriculture more sustainable, surprisingly small resources are being spent on these long-term projects. Most of the plant breeding takes place in private companies, and naturally their focus is on products that can be marketed in the not too distant future and on a global market. This type of future-oriented research needs public funding, but, unfortunately, governments in most countries – including Sweden – spend very little money on this area. As a result, important long-term projects do not get the funding they need.

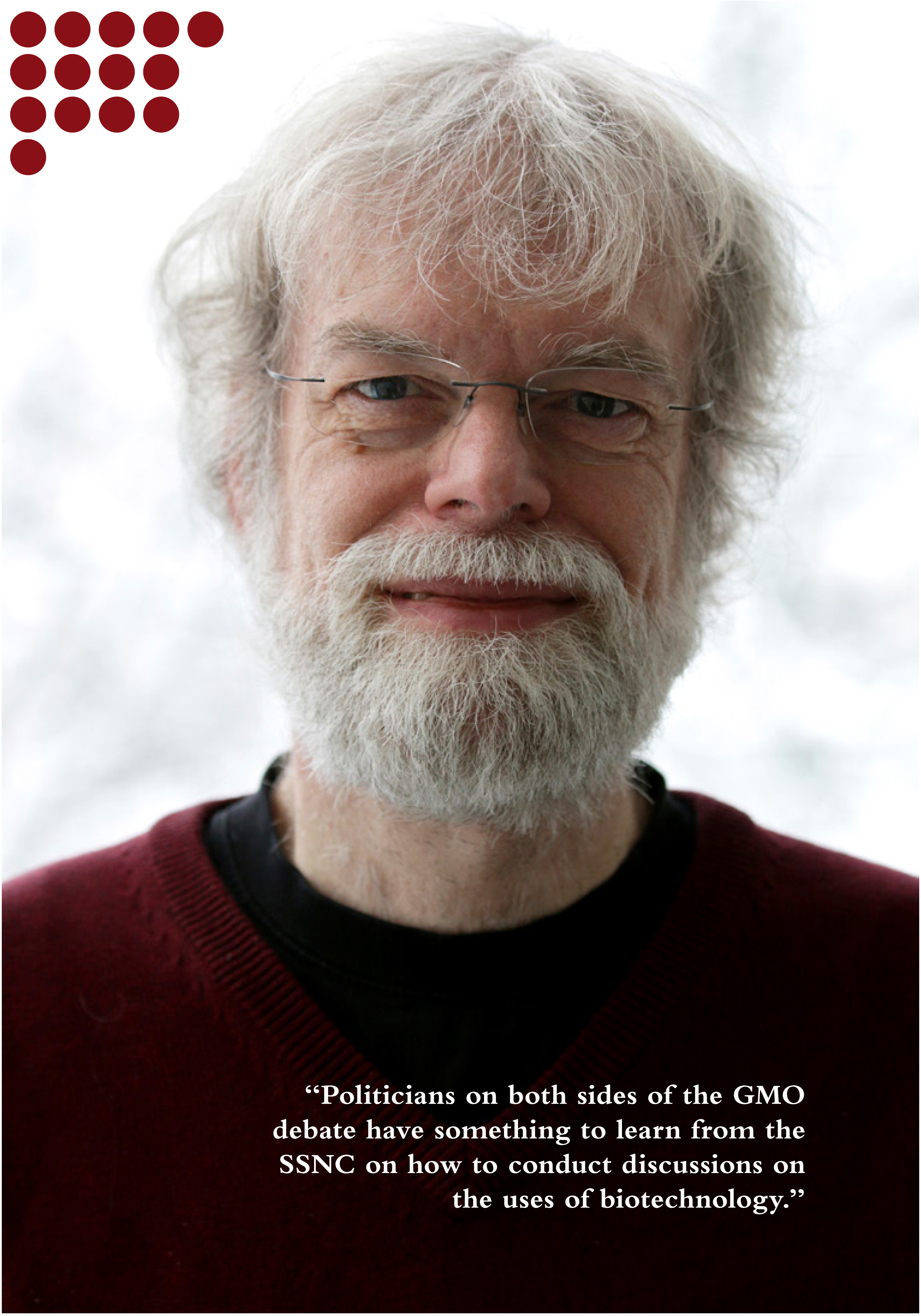
At the same time, research from the health sector has shown again and again how important food is for our health. Changing food habits is not easy, but plant breeding is one of several measures needed to improve the nutritional quality of our food. One major focus is enhancing fat and starch composition, both of which are subjects of research at Mistra Biotech. Many of the nutritional improvements also require long-term research, and because such research might not be profitable in the short run it is also in much need of public funding.

Researchers in our programme who work with animal breeding have convinced me that there is a pressing need for breeding that has a strong focus on animal health. For instance, reduced incidence of mastitis is an important goal in cattle breeding. Unfortunately, breeding for animal health is yet another example of long-term research that tends to be severely underfunded unless public resources are used.

Private companies provide farmers with improved products every year, and it is not my purpose to disparage the research and development that they perform. But it is unrealistic to expect them to do all that is needed in this area. Let me make a comparison. No one expects industry to perform all the research that we need to improve healthcare. Their research is indispensable, but the need for publicly funded medical research is obvious. Publicly and privately funded research complement each other in this area, and in the same way we need publicly funded research that complements private research in plant and animal breeding.

Inger Andersson
Chair of the Board

« Inger Andersson, Former Director General of the Swedish National Food Agency.



"Politicians on both sides of the GMO debate have something to learn from the SSNC on how to conduct discussions on the uses of biotechnology."

A new way to talk about biotechnology

Mistra Biotech is a research programme, and not surprisingly there are different opinions among researchers in the programme on some of the issues concerning agricultural biotechnology. But I believe that we are all tired of sweeping statements such as "All GMOs are dangerous" or "All GMOs are safe" that are often heard in the public debate. As researchers, we want each question about the uses of biotechnology to be carefully analysed on the basis of the best scientific evidence.

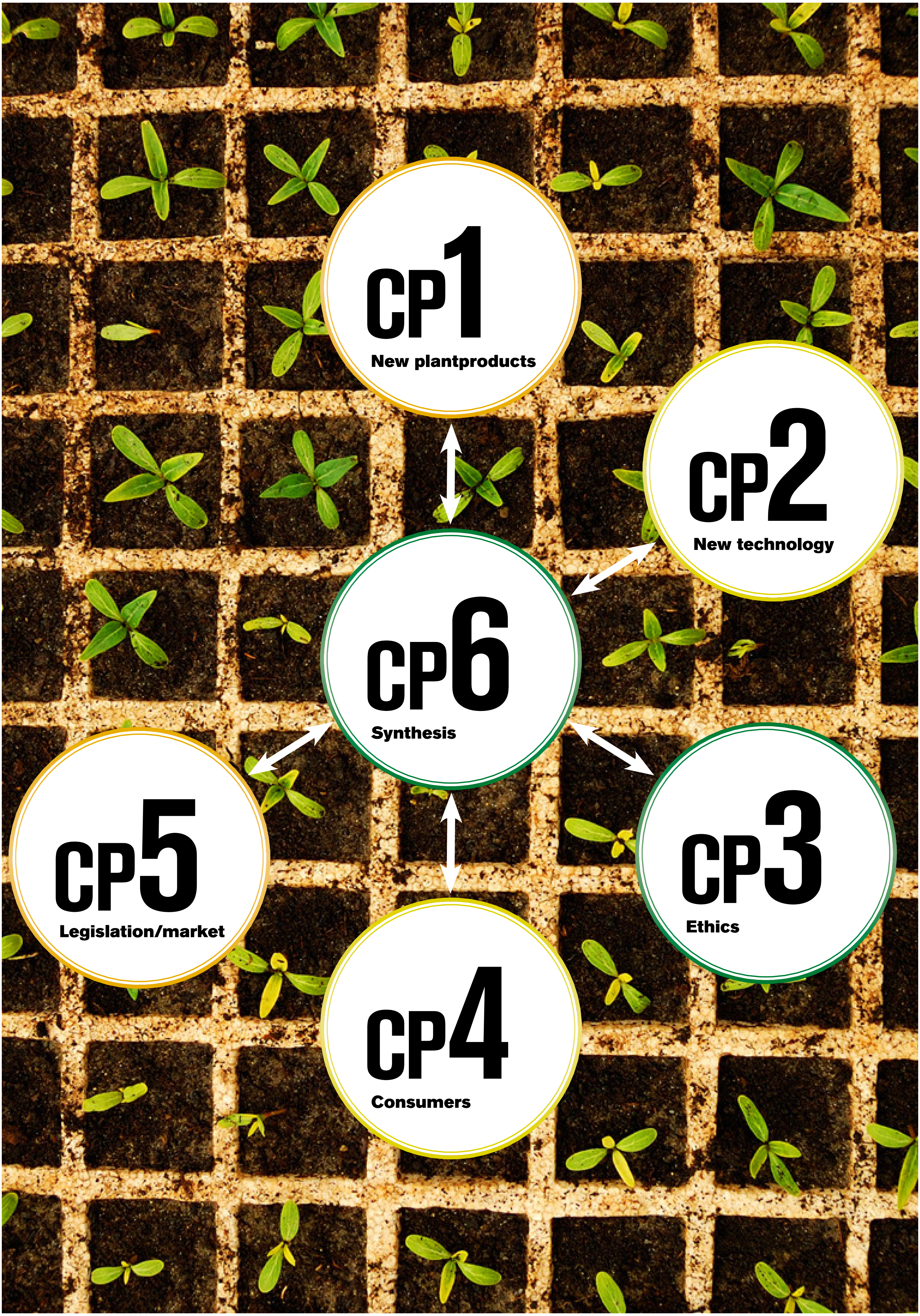
In April 2014, the Swedish Society for Nature Conservation (SSNC) adopted a new GMO policy that is quite interesting from this point of view. Not surprisingly, the Society has strict environmental demands on the products that are the result of genetic modification, but they also emphasize that assessments have to be made "in each particular case" and that both risks and advantages should be evaluated. Currently, they require "extensive risk assessments" for all genetically modified cultivars. However, when more experience has been gained "it should be possible to develop rules for assessing and managing genetically modified organisms in about the same way as industrial chemicals. Some can be used with conventional risk assessment and risk management, others with precaution as the leading principle, while yet others should be subject to strict restrictions, just like serious environmental poisons."

This policy document gives some indications of how the SSNC views different types of cultivars. They are critical of the use of herbicide-tolerant crops, and judging by the argumentation this also applies to herbicide-tolerant crops that are not genetically modified. On the other hand, they are in principle positive to cultivars with resistance to *Phytophthora infestans* (the pathogen that causes potato late blight). The reason for their positive attitude in the latter case is that such cultivars are expected to reduce the use of fungicides without bringing any other environmental problems. The Society also foresees that some genetically modified industrial crops can have "positive applications", but they emphasize the need for careful analysis and an adequate regulatory system in these cases as well.

There might be different views on the merits and demerits of these and other biotechnological products, but what is important here is the way in which GMOs are discussed in the policy. The SSNC issues no sweeping statements about all GMOs one way or the other. Instead, they promote a careful, science-based analysis in each particular case. And that is exactly what we researchers want policy-makers to do. It is our task as researchers to provide decision-makers with the best possible scientific information on the potential risks and the potential benefits of different biotechnological products. Naturally, we hope that policy-makers will make use of this information and base their decisions on the best available scientific information. This might not lead to complete agreement, but it should lead to a sensible discussion in which all participants make use of the common knowledge base that science provides. Politicians on both sides of the GMO debate have something to learn from the SSNC on how to conduct discussions on the uses of biotechnology.

Sven Ove Hansson
Programme Director

« Sven Ove Hansson, Professor in Philosophy at the Royal Institute of Technology (KTH) and Guest Professor at the Department of Crop Production Ecology, SLU.


CP1
New plantproducts
CP2
New technology
CP6
Synthesis
CP5
Legislation/market
CP3
Ethics
CP4
Consumers

Mistra Biotech

Mistra Biotech is an interdisciplinary research programme focusing on 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 more sustainable food production with healthier products and fewer environmental impacts. With ability comes responsibility, and we take the concerns that have been raised about potential negative effects of biotechnology applications 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 has its focus on the social, economic, and ethical aspects of the use of biotechnology in agricultural production. We study consumer attitudes and behaviours related to the use of agricultural biotechnology for food products and investigate issues related to governance and regulation in the Swedish agri-food system. Our social research has a strong focus on sustainability issues and on the perspectives of stakeholders in the food production systems. Research at Mistra Biotech is organised into six component projects (CPs). Five of these focus on the following research areas: new plant products, new technologies, ethics, consumer attitudes, and legislations/markets. The results from these CPs are integrated into the sixth CP that focus on analysis and synthesis.

Mistra Biotech involves over 70 researchers. Most are at SLU, but some work at KTH, Lund University, and other academic institutions. The programme also includes international collaborations with Aarhus University, the University of Edinburgh, and other institutions. Mistra Biotech is funded by Mistra, 10 million SEK per year for 2012 to 2015. The programme will apply for phase-two funding for an additional four years. SLU co-funds the programme by matching the Mistra funding with a further 10 million SEK. Many companies, agencies, and organisations also support the programme with their knowledge, experience, and valuable feedback. Lantmännen SW Seed AB also contributes financially with a sum of 50,000 SEK per year.

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

« *The research in Mistra Biotech is organised in six component projects (CPs). The results from CP1-CP5 are integrated into the sixth CP that focuses on analysis and synthesis.*

Mistra Biotech component projects

CP1 PLANT BIOTECHNOLOGY FOR INNOVATIVE PRODUCTS

In this project, we are developing the wild biennial species *Lepidium campestre* (field cress, also known as field pepperweed) as an oil and catch crop. A catch crop is one that is sown under cereal crops during the spring with the aim of reducing soil tillage and mitigating nutrient leaching. Using both genetic modification (GM) and non-GM techniques enables us to compare the effects of different breeding methods on the improvement of important agronomic traits, as well as to speed up the breeding process. The main targeted traits in field cress are increased oil content and quality, increased seed yield, and reduced pod shattering (i.e., seed drop before harvest), which causes huge losses in seed yield.

To reduce reliance on fertilizers and pesticides in barley and potatoes, our work focuses on making nitrogen use more efficient and on improving pathogen resistance.

We are focusing on health issues by developing a potato with a low glycaemic index, breeding for high oleic acid oil in field cress, and analysing the structure and properties of starch from different types of barley. The quality of starch is of great importance in both human food and animal feed, but the starch can have different properties depending on granular size distribution, composition, and the chemical structure of the individual starch components.

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Collaborations:
Lantmännen, SW Seed AB
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Swedish Rural Economy and Agricultural Societies, Kristianstad
The GenePool Ashworth Laboratories, University of Edinburgh
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Prof. Leif Bülow, Dept of Pure and Applied Biochemistry, Lund University
Prof. Thordal-Christensen's group, Copenhagen University
Ass. Prof. Robert S. Brueggeman, North Dakota State University

CP2 NOVEL MOLECULAR BREEDING TOOLS

Most economically important traits in crops and livestock that influence either product yield or disease resistance are complex traits governed by many genes and their interactions with environmental factors. Traditional breeding approaches use pedigree information and statistical tools to estimate the proportion of variation that is due to heritable factors, but these methods treat the genome as a "black box". Today's new technologies facilitate genome sequencing at a fraction of the original costs of only a few years ago, and we are developing methods and tools for the use of whole genome sequence data in breeding, that is, selecting plants and animals based on information about the entirety of their DNA instead of just looking at specific genes. Because traits in plants are often largely dependent on environmental factors, the need to implement these factors into selection tools presents challenges for molecular breeding. Similar challenges also provide opportunities for improved use of molecular breeding tools in cattle. We are also investigating the potential to use information about proteins – the products of the genome – in breeding in order to screen for and select suitable plants and animals at an early stage in the breeding process.

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Collaborations:
Lantmännen, SW Seed AB
Viking Genetics, Skara
SciLife Laboratory, Uppsala
Aarhus University, Denmark
LUKE (former Agrifood Research), Finland
Edinburgh Genomics, University of Edinburgh, UK

CP3 ETHICS

The debate about ethical issues in biotechnology and its applications is deeply polarized. Despite extensive literature on the ethics of technology in general, there is a shortage of studies carried out in close collaboration with the scientists who actually develop these technologies. Therefore, much of the debate is insufficiently informed by recent developments and is rather sweeping in character. Also, few ethical assessments of the applications of technology have dealt new biotechnologies, and even fewer take into account the potentially positive environmental and health impacts of agricultural applications of biotechnology in a systematic way. We hope to provide a structured method for making this debate less polarized so as to allow everyone to better understand each other's arguments.

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CP4 CONSUMER ATTITUDES

Why do consumers act as they do? What are the driving forces behind attitudes and behaviours when it comes to food produced using agricultural biotechnology? What is our perception of risks and trust? We hope to reach a better understanding of the underlying consumer-related issues that will play an essential role in the acceptance and use of agricultural biotechnology in Sweden. The research in this component project focuses on in-depth studies of the driving forces behind consumer attitudes and behaviours related to the use of agricultural biotechnology for food products. This project explores the psychological foundations of technology acceptance, risk perceptions, choice, and trust among members of the general public in their roles as consumers.

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CP5 SWEDISH COMPETITIVENESS

The economic and regulatory environment in which firms operate has a direct effect on their ability to produce, and to adopt, new technologies. Firms produce innovations when they have the ability to commercialize their products or services at a profit, and the profitability of an innovation depends on the degree to which firms are able to capture the economic benefits generated by their innovations. We analyse the structure and governance of the Swedish agri-food system and the national and international regulatory environments. We also explore Sweden's capacity to produce and distribute innovative products and processes, the constraints on this capacity, and the impact of all of this on the Swedish economy.

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CP6 CENTRE FOR AGRICULTURE AND FOOD SYSTEMS ANALYSIS AND SYNTHESIS, AgriSA

The work in this project focuses on whole production systems and stretches across disciplines within the human, agricultural, natural, and social sciences. AgriSA is a hub where the information and results from all Mistra Biotech projects are processed and where overall syntheses are made and communicated to stakeholder groups. The project is also a platform for collaboration between researchers involved in Mistra Biotech's CPs and other researchers. The aim of this work is to understand and facilitate the implementation of sustainable food production using biotechnology as a tool.

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A paradigm shift?

Already in the oldest part of the Bible, man is defined as the ruler of the world.

> *"Then God said, 'Let us make mankind in our image, in our likeness, so that they may rule over the fish in the sea and the birds in the sky, over the livestock and all the wild animals, and over all the creatures that move along the ground'." (Genesis 1:26)*

This indicates that man very early saw himself as sovereign with the right to reconstruct and change nature after his needs and wishes. So it has remained. Man has proven to be a tough ruler rather than a mild and understanding caretaker. Nature was to be tamed and exploited.

It is understandable that a long time ago when life was an on-going fight for survival there was not much space for mildness and nursing. And it is also true that humans many times did not realise that they were causing problems with, and even the destruction of, entire ecosystems. This hard-handed master did not always understand the complexity of nature and the functions of ecosystems. He often took what he needed from the available natural resources and moved on to new areas when there was nothing left to take.

"We can imitate nature and thereby act in accordance with it"

Surely there have always been those questioning such development, and during the course of industrialisation the doubts have become more intense. But it is only during the last sixty years that criticism has become more general. With ruling comes responsibilities, and some of us even question man's right to rule the world. We have to define our role in nature in a new way. We need to start asking questions. What can we allow our selves to do with other living creatures, with plants and trees, and with other natural resources?

We have been tremendously successful as a species. From being almost extinct, we have invaded all continents on the earth and there are now more than 7 billion individuals living on this planet. We have made fantastic discoveries and inventions. But this success has come at a cost for nature. Climate change, loss of biodiversity, and loss of fertile soils are just a few. And payback time is approaching. How can we repair the damage that we have caused and at the same time improve living conditions for the still growing, and to a large extent hungry, world population? This is the question at the core of the controversy surrounding modern biotechnology.

Some of us see the new insights into biological mechanisms as tools for change. Instead of exploiting nature and forcing it to obey us, we can learn from nature, understand how natural mechanisms work, and then create similar systems. We can imitate nature and thereby act in accordance with it. This is a paradigm shift.

Some, however, see modern biotechnology as more of the same, as a tool for continued exploitation and destruction. They find evidence in the way the first generation of GM crops was developed and used. Irresponsible ways of using glyphosate-resistant crops have, for example, increased the speed with which weeds develop resistance, and this has led to the renewed use of dangerous chemicals that we had hoped to phase out.

Those of us who are convinced that biotech can help us meet the grand challenges, and those who fear for the opposite, have a common goal. We all want a better future for mankind and for the planet Earth. We need to trust each other and put this common interest at the forefront. We need to listen more (and preach less) to each other. Only by doing so can we create a constructive discussion. In such a process, Mistra Biotech has an important role to play.

Annika Åhnberg
Former Minister of Agriculture, and honorary doctorate at SLU.

« Annika Åhnberg.

The potato – long history and many applications

The tubers of potato are feeding humans in many parts of the world and its rich starch content also makes it valuable for different industrial applications. However, breeders and growers have to compete with several pathogens and pests who also finds the plant attractive.

8000 YEARS OLD CROP

There are about 100 species of wild potato and these can be found in a wide range of habitats, including dry deciduous forests of Mexico (the suggested origin of the plant) and the USA, Chilean beaches, cool rain forests in the eastern Andes, and high-altitude Andean grasslands.

The modern cultivated potato dates back nearly 8,000 years to the Andes on the border between Bolivia and Peru. In the 1570s, cultivated potatoes were introduced into Europe and, from there, distributed throughout the world from the late 17th century onwards. Potatoes are now grown in 149 countries at a wide array of latitudes and altitudes and on all continents except Antarctica. The potato ranks as the 3rd most important food crop worldwide behind rice and wheat, and it has steadily expanded globally with a strong increase in Asia and Africa. Production in Europe has, however, declined.

MORE THAN MASH AND FRIES

Potato yields vary considerably across the world, with the lowest being in sub-Saharan Africa. In 2013, China was by far the biggest potato producer followed by India and The Russian Federation. About half of the global crop is consumed fresh, and the other half is processed into food products and animal feed or provides seed tubers for the following season's crop. Potatoes are an important source of starch, which has some unique features compared to starches from cereals. For example, high phosphate content and very large, smooth granules make potato starch suitable for the manufacture of high-quality paper.

Depending on what the potato will be used for, the quality requirements can be rather different. However, both industry and consumers tend to avoid those with growth cracking, mechanical damage and bruising, greening, hollow hearts, brown centres, and internal rust spots.

The processing industry requires a high dry-matter content because this is associated with a high yield of product and low oil absorption. As a table food, however, high dry-matter content is not preferred because the potato will tend to crumble when boiled. There are also requirements for tuber shape. Round potatoes are good for making chips and long oval ones for French fries. Regular shapes with shallow eyes are preferred for processing and table use to reduce wastage.

The starch composition is not just interesting for industrial use, and it has gained interest due to the possibility to change the ratio of amylose and amylopectin through genetic modification. Shifting the proportions towards amylose results in slower absorption of glucose in the intestine and hence a lower glycaemic index, which is considered desirable to reduce the incidence of type-2 diabetes and cardiovascular disease (read more about this on page 24).

MANY THREATS TO CULTIVATION

Many factors influence yields, including weather, fertilizer, fungicides, insecticides, modern agricultural technology, and water availability. The potato is very sensitive to drought because of its sparse and shallow root system, and irrigation plays an effective role in producing high yields in many parts of the world. The potato originated in regions with cool temperatures, thus in many genotypes tuber yield is highly sensitive to elevated temperature.

Potato pests and pathogens require considerable pesticide inputs for those that can be chemically controlled. Serious losses in yield and reductions in quality can occur when potato plants and tubers are eaten by insects, mites, and nematodes or succumb to fungal, bacterial, and viral diseases. One of the key factors in the spread of disease is continued use of home-grown seed and the lack of sufficient land for rotation, which leads to a build-up of pests and pathogens in the soil and in seed tuber stocks.

The most widespread and economically significant threat to potato production is late blight caused by the pathogen *Phytophthora infestans*. In many parts of the world, fungicide application is the only means to prevent this disease, and fungicides might be applied as regularly as every 4 days.

Other prominent threats include nematodes (roundworms) that feed on roots or enter the host and cause damage as they migrate through tissues and feed, or cyst nematodes (probably introduced to Europe around 1850 with potatoes taken from South America in the search for resistance towards *P. infestans* after the potato blight epidemics of the 1840s). Bacterial infections in potatoes are spread through soil and host debris, numerous weed hosts, and irrigation water. In addition, about 37 viruses infect potatoes, but only about one third of them cause economically important diseases. Many viruses are spread by insects and can lead to curling, yellowing, or mosaic symptoms on leaves, and to the stunting of plants. Some affect tuber quality and produce brown or necrotic marks and lines on tubers.

The most notorious of the potato insect pests is the Colorado potato beetle (Leptinotarsa decemlineata).

It is established in many parts of the world, but its range is still restricted by cold temperature. Both the beetle and its larvae feed on potato leaves, and an uncontrolled infestation can severely damage crop yield.

Leaf miners feed within the leaves, and below the ground potatoes are damaged by insect larvae, especially wireworms that tunnel into the tubers, and can be found throughout the world. Thrips, whiteflies, aphids, and leafhoppers are other insects that cause less damage unless the infestations become severe.

One important factor for preventing pest problems in potato production is a supply of disease-free planting material. Seed production has been traditionally more successful in countries with cooler climates because these countries have fewer insect vectors and thus reduced problems with viruses and diseases. In the 1970s, *in vitro* tissue culture (micropropagation) was adopted as a means of multiplying disease-free plants from favourable genotypes to generate healthy seed tubers. Additionally, most of the major potato-growing countries established seed certification systems in the early 20th century to ensure certain standards in lineage and health of seed potatoes. These systems help to ensure that varieties remain genetically pure and disease-free with clear regulations and labelling through production, harvesting, storage, and trade for each lot of seed.

BREEDING POTATOES

In the domestication of the potato, one of the first traits that humans probably selected against was steroidal glycoalkaloids (e.g. solanin), which is part of the plant's defence against pests and pathogens. These are potentially toxic compounds with a bitter taste and are found throughout the family Solanaceae. Even today it is important for breeders to check the levels of these glycoalkaloids, especially if they use a wild species as a source of a desired trait.

Modern potato breeding began in 1807 when the first deliberate crosses between varieties were made, and during 19th century many new cultivars were produced in Europe and North America. Today more than 4,000 cultivars are recognized globally, but it is thought that their genetic base is a relatively small sample of clones from the Andes and coastal Chile.

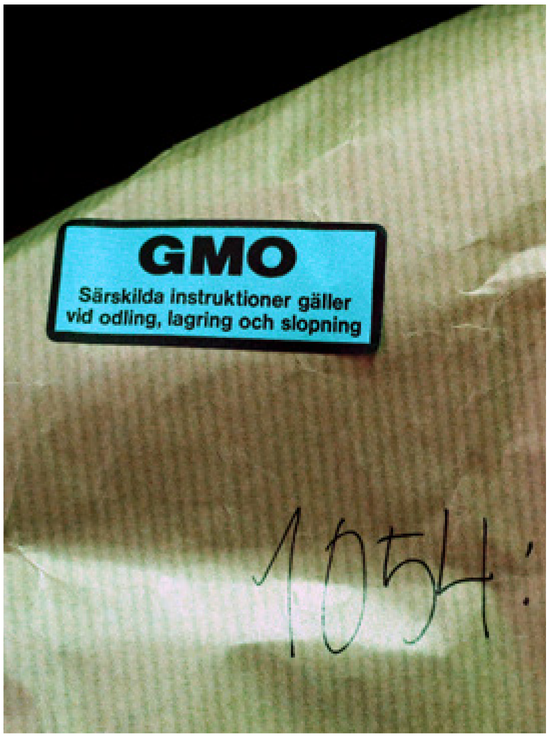
As in plant breeding in general, potato breeding involves making crosses between pairs of parents with complementary features to generate individuals with as many desirable characteristics as possible. Today, breeders can complement phenotypic assessments with a gentoypic asssessment of the breeding material. Major genes have been mapped for several target traits, but many economically important traits appear to be complex polygenic traits (traits affected by several genes).

Breeding potato can be challenging. The main European cultivated potato *Solanum tuberosum* is a tetraploid (it has four sets of chromosomes) and suffers from inbreeding depression. Throughout history there have been a number of hybridisations between different species resulting in triploids, tetraploids, and pentaploids, which can make crossings difficult. However, increasing knowledge of key genes, developmental mechanisms, physiology, water and nutrient use, and resistance to biotic and abiotic stresses have allowed for faster breeding using several biotechnological approaches.

Molecular markers are available for several major genes for disease resistance. Combining such genes, together with alleles (gene variants) that have a combined effect on resistance, can remove the need for costly and complex disease testing. Genetic modification is another option. Transgenic resistance to viruses was demonstrated in the 1980s, and virus-resistant transgenic potatoes were commercialised in the mid-1990s. However, negative consumer attitudes to genetically modified plants put a halt to further commercialisation. A few other GM potatoes have been commercialised in recent years, for example, the starch potato Amflora (produced for industrial use) that was grown for a couple of years in Sweden, Germany, and the Czech Republic. Last year, the Simplot Innate GM potato, which is bred to produce less acrylamide when fried and to resist bruising, was approved in the USA.

Resistance against *P. infestans* (read more on page 20) and other pathogens and insect pests, modified starch and nutrition levels (such as the high-carotene "Golden" tubers), and tolerance to abiotic stresses such as drought, heat, cold, mineral deficiency, and salinity are all examples of traits that researchers and breeders are focusing on today.

Read more in Birch *et al.* (2012) Crops that feed the world 8: Potato: are the trends of increased global production sustainable? *Food Security* 4: 477-508


GMO
Särskilda instruktioner gäller
vid odling, lagring och slopning
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Mistra Biotech

selections from 2014

In this section we present some of the results from Mistra Biotech's third year, some are not published yet. Sign up for our newsletter on www.slu.se/mistrabiotech to follow our achievements.

Potato breeding in the Nordic countries

Contact: *Dennis Eriksson, dennis.eriksson@slu.se*

Dennis Eriksson and several others at SLU are currently working on a review of the present situation regarding potato breeding, cultivation, processing, and consumption in the Fennoscandian region. The potato is the world's third largest staple crop and is an important and almost irreplaceable part of the diet in Sweden, Norway, and Finland. However, consumption tends to be based on regional production because the potato is not a commodity that is actively traded on the world market. Therefore, the supply of potatoes depends heavily on varieties that are adapted to the particular conditions and demands in the region in which they are grown. In the case of the Fennoscandian countries, this includes relatively short and intense growing seasons with long day lengths, specific pathogen pressure, and particular consumer preferences. In Sweden and Norway, we have comparatively small breeding programmes, whereas in Finland the potato breeding programme ceased in 2014. At the same time though, the potato has the highest yield potential of all crops in the Nordic region. The review, which will be published in 2015, will discuss some future lines of development such as an integrated breeding strategy for Sweden, Norway, and Finland.

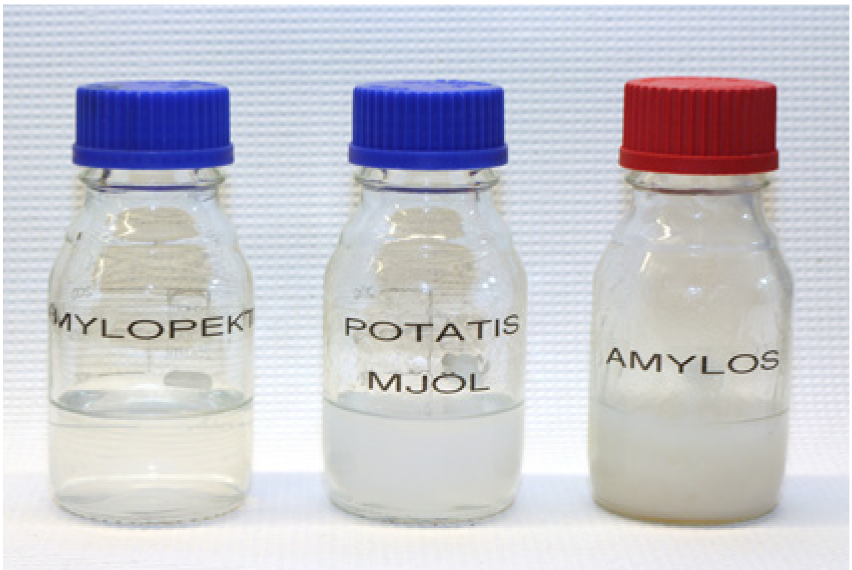
"potato has the highest yield potential of all crops in the Nordic region"

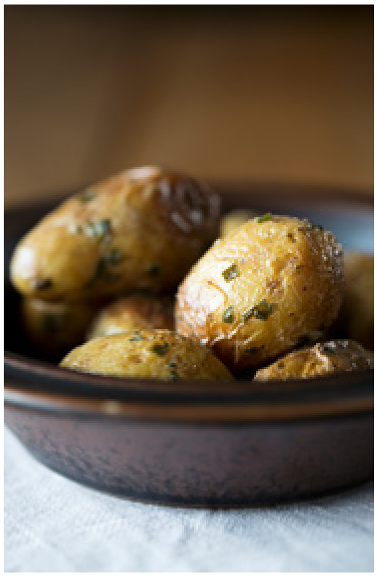
Battling potato blight

Contact: *Erik Andreasson, erik.andreasson@slu.se*

As described previously, late blight caused by *P. infestans* is a severe problem in potato production. For a plant to combat diseases, a toolbox with many different resistance mechanisms is needed, especially when it comes to *P. infestans* in Sweden where the pathogen has an unusually high local diversity. Breeders and researchers have previously found that a specific potato breeding clone (SW93-1015) has an efficient resistance against *P. infestans* under field conditions. Interestingly, this clone has some characteristics that are different from other potato clones with a similar type of resistance (so-called R-gene–mediated resistance). For example, the SW93-1015 clone shows a lower hypersensitive response to infection (which is a reaction where the plant stops a pathogen infection by killing off its own cells surrounding the infected area), but elevated levels of hydrogen peroxide (H_2O_2), which is a stress-signalling molecule in plants.

Analysis of 76 F1 (the first generation) potato progenies from two individual crosses showed that nearly 50% of the clones from both crosses were resistant. This suggests that the SW93-1015 clone has a simplex genotype for this trait, i.e. that it only has one allele (gene variant) for the trait of interest. However, the researchers could not correlate the H_2O_2 levels with *Phytophthora* resistance. By analysing the RNA of over 50 clones, they discovered a new DNA marker for the resistance trait of SW93-1015 that was then used to track down eight variants (gene homologs) of the resistance gene, of which seven had never been described before. Even though only a few amino acids differed between the gene homologs, only one worked when inserted into the sensitive potato cultivar Desiree. The developed marker is now used in the Swedish breeding programme. This work also shows how the use of pathogen molecules can speed up the breeding process.





Because all potatoes have the same 1:4 ratio of amylose to amylopectin, this composition cannot be changed through crossings. Through molecular genetics, however, the ratios can be adjusted, and thereby give us a potato with a lower glyceamic index. (Left photo: Potato starch heated in water. Jars from left to right; amylopectin, non-separated starch, and amylose.)

Late blight, caused by Phytophthora infestans, is a serious potato disease that often requires continuous applications of fungicides. The photo shows susceptible and resistant potato varieties in a P. infestans infested field.

Precise editing of (potato) genes

Contact: *Li-Hua Zhu, li-hua.zhu@slu.se*

In parallel with investigations into gene functions in the plants, new methods and techniques to edit the genes have been developed. One fairly new and promising method of controlling the expression of genes in plants is site-directed mutagenesis. This method has been developed to overcome the problem of randomness that results from traditional mutation breeding. These techniques allow particular sequences in a given gene to be modified in a specific manner. Site-directed mutagenesis can be achieved with different techniques, and one of the most powerful ones is the use of transcription activator-like effector nucleases (TALENs).

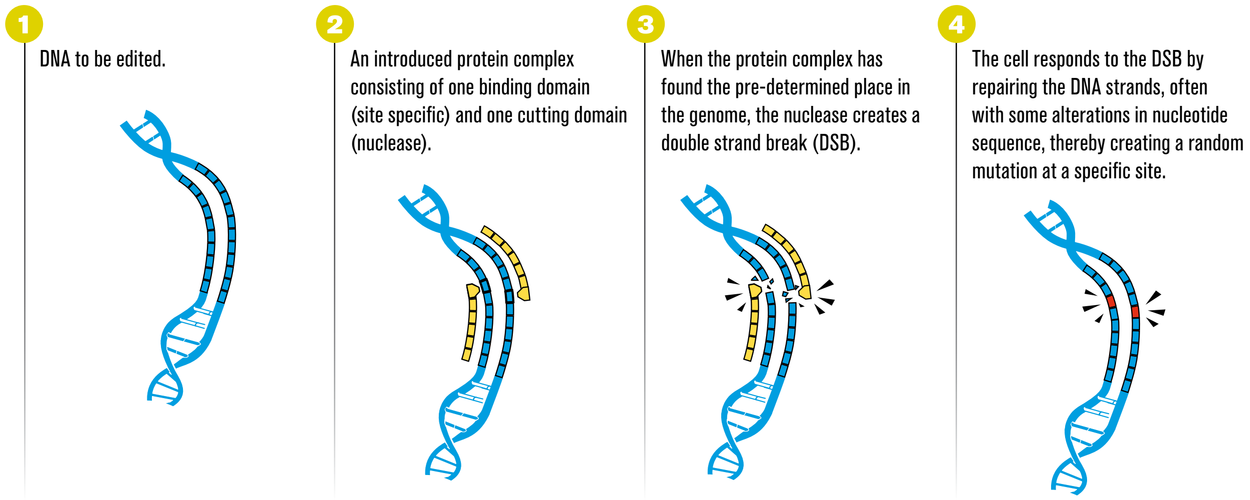
TALENs have a customized DNA-binding domain fused to a non-specific nuclease domain. The DNA-binding domain consists of a long modular structure derived from the bacterium *Xanthomonas*. The nuclease domain can cut the DNA strand at a single nucleotide, and each module can be engineered to recognize DNA sequences up to 30 base pairs, which makes it very specific to a certain sequence. TALENs enable the introduction of double-strand breaks into virtually any DNA sequence with high efficiency in plants, and this technique is predicted to have broad applications in the future. TALENs can be used either to introduce an error (to knock out a target gene by transient gene expression) or to introduce a new DNA sequence into the target site – that is, to add a new trait, which will be introduced by genetic transformation (illustrated in the following figure). Whether the plant is classified as a GMO or not might depend on which variant of the technique is used, but this is still unclear in the EU.

A group of researchers at SLU in Alnarp, with Alessandro Nicolia in the lead, has developed a method for site-directed mutagenesis using TALENs in tetraploid potatoes. They have shown that the site-directed mutagenesis technology can be used as a new breeding method in potatoes as well as for functional analysis of important genes to promote sustainable potato production.

Alessandro, N., Proux-Wéra, E., Åhman, I., Onkokesung, N., Andreasson, E., & Zhu, L-H. Targeted gene mutation in tetraploid potato through transient TALEN expression in protoplasts. Submitted.

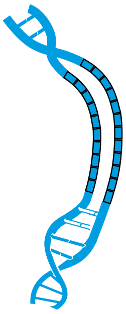
Transcription Activator-Like Effector Nucleases (TALENs) are examples of what is called Site Directed Nucleases (SDNs) techniques, used to edit DNA. Common for all SDNs is that a cutting domain is combined with a designed binding domain that will determine where the cut will be made. In the first example the protein complex can be introduced via DNA, mRNA, or as a pre-made complex. It is only in the third example that introduced DNA is incorporated into the genome.

SDN 1

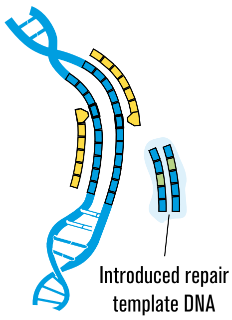


SDN 2

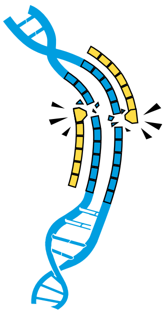
1 DNA to be edited.



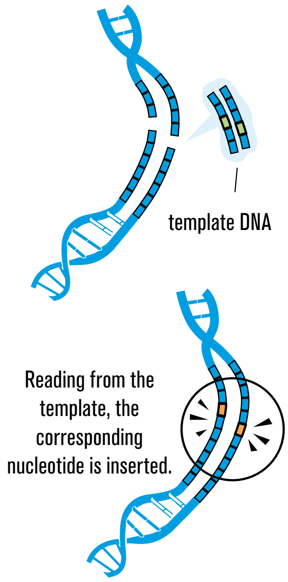
2 As in SDN1 an introduced protein complex consisting of one binding domain and one cutting domain binds to a specific site. But in this case also a short DNA strand is added. This template is homologous to the target area, with the exception of the specific base alterations to be introduced.



3 When the protien complex has found the pre-determined place in the genome, the nuclease creates a DSB.

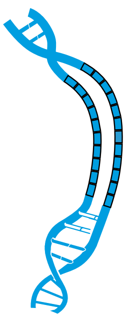


4 As in SDN1 the DNA repair system responds, but in this case the introduced DNA will be used as template for a specific nucleotide change.

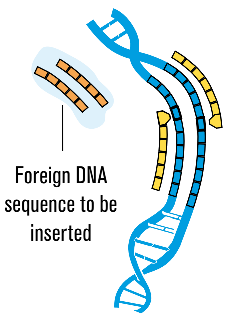


SDN 3

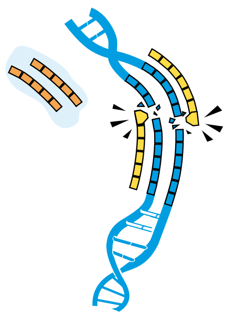
1 DNA to be edited.



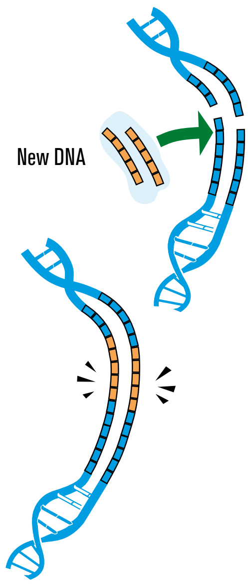
2 As in SDN1 and 2 an introduced protein complex consisting of one binding domain and one cutting domain binds to a specific site in the genome. But in this case a DNA strand that you wish to add to the genome is inserted.

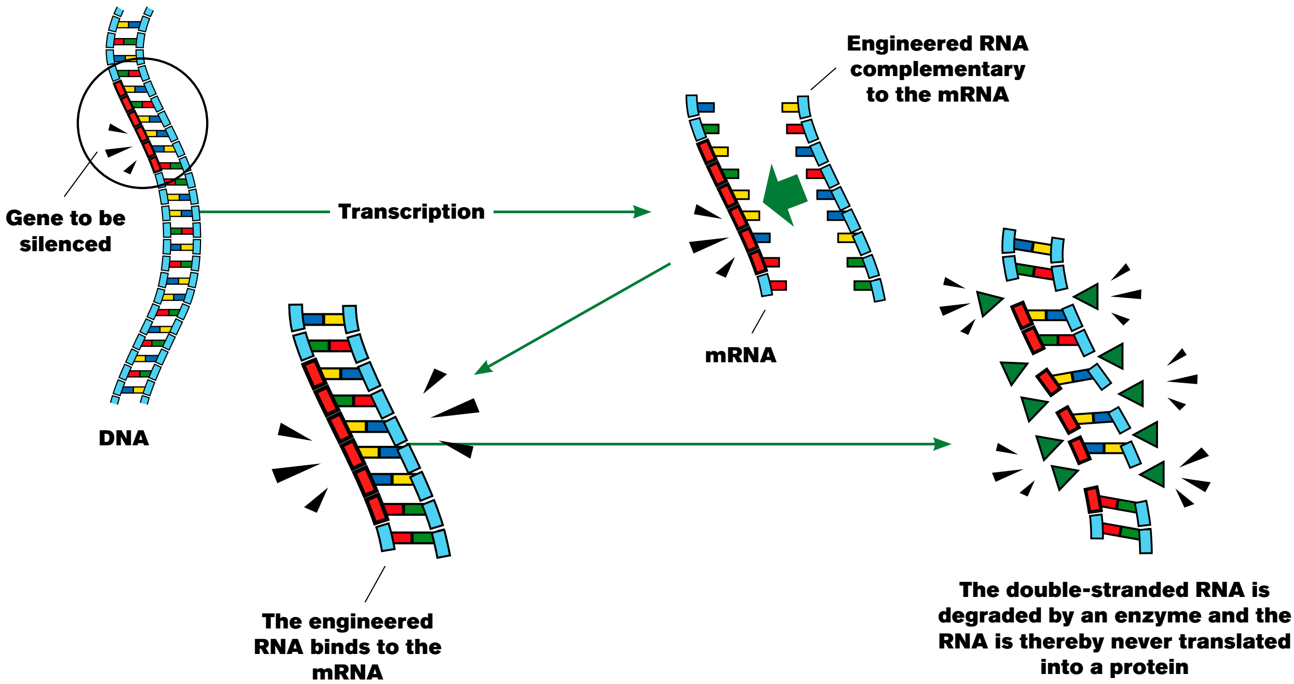


3 When the protien complex has found the pre-determined place in the genome, the nuclease creates a DSB.



4 The inserted DNA is designed to fit the ends of the DNA break and is ligated into the strand.





This principle of RNA interference (RNAi) is used for down-regulating the expression levels of target genes by preventing mRNA from being translated into a protein. A gene that codes for a RNA strand complementary to the gene's mRNA is transferred into the genome. The two RNA strands pair up to form a double-stranded RNA. In plants mRNA normally only exist as single strands, and double-stranded RNA is quickly degraded by the cellular enzymes that protect the plant against viruses.

A low glycaemic index potato

Contact: *Mariette Andersson, mariette.andersson@slu.se*

Starch is usually made up of 25% amylose and 75% amylopectin. In our bodies, amylopectin is easily degraded, which contributes to a high glycaemic index (GI) in foods rich in starch. Amylose, on the other hand, takes longer to digest, and this results in a slower uptake of glucose (and thereby a lower GI) if we eat products with higher proportion of amylose. The slow and steady digestion is favourable for diabetic patients, but amylose can also be good for weight loss because of the prolonged sense of satiation. Starches with high amylose levels also have a probiotic effect and promote the growth of beneficial gut bacteria that are known to be beneficial to our immune system and to lower cholesterol levels.

Because all potatoes have the same 1:4 ratio of amylose to amylopectin, this composition cannot be changed through crossings. Through molecular genetics, however, the ratios can be adjusted. By turning off two genes that code for enzymes involved in the building of amylopectin though a technique called RNA-interference (see the description in the figure above), Mariette Andersson and colleagues at SLU Alnarp have succeeded in increasing the proportion of amylose starch in potatoes by up to 70%. However, a major drawback with the high-amylose trait is a severe decrease in total starch content as a result of the modification. On the other hand, the researchers found an increase in tuber yield in the potato line with the highest amylose content, which somewhat compensates for the lower total starch content. To circumvent the starch yield drag, research with the aim to increase starch content in high-amylose potatoes is on-going. Of special interest is a potato variety named Verba, which has an extraordinarily high starch content. In initial experiments, high-amylose Verba was produced in the same way as described above and the starch content in this line was significantly higher compared to other high-amylose lines. Verba is, however, not suitable for commercial growth due to a low tuber yield and severe susceptibility to pathogens. Nonetheless, Verba has potential as a gene source for increased starch yield, and Mariette and colleagues are using transcriptome profiling (a method where one looks at all RNA sequences in a certain tissue at a certain time) to determine what is regulating this high starch content. This will give indications of unknown regulatory elements and/or genes with altered expression that are responsible for the high starch trait, and "high starch" gene candidates can then be inserted into a high-amylose potato. The project is continuing with studies of crossings between a high-amylose line and Verba in both greenhouse and field trials.

Influence of GMOs on ecosystem processes

Contact: *Anna-Karin Kolseth, anna-karin.kolseth@slu.se*

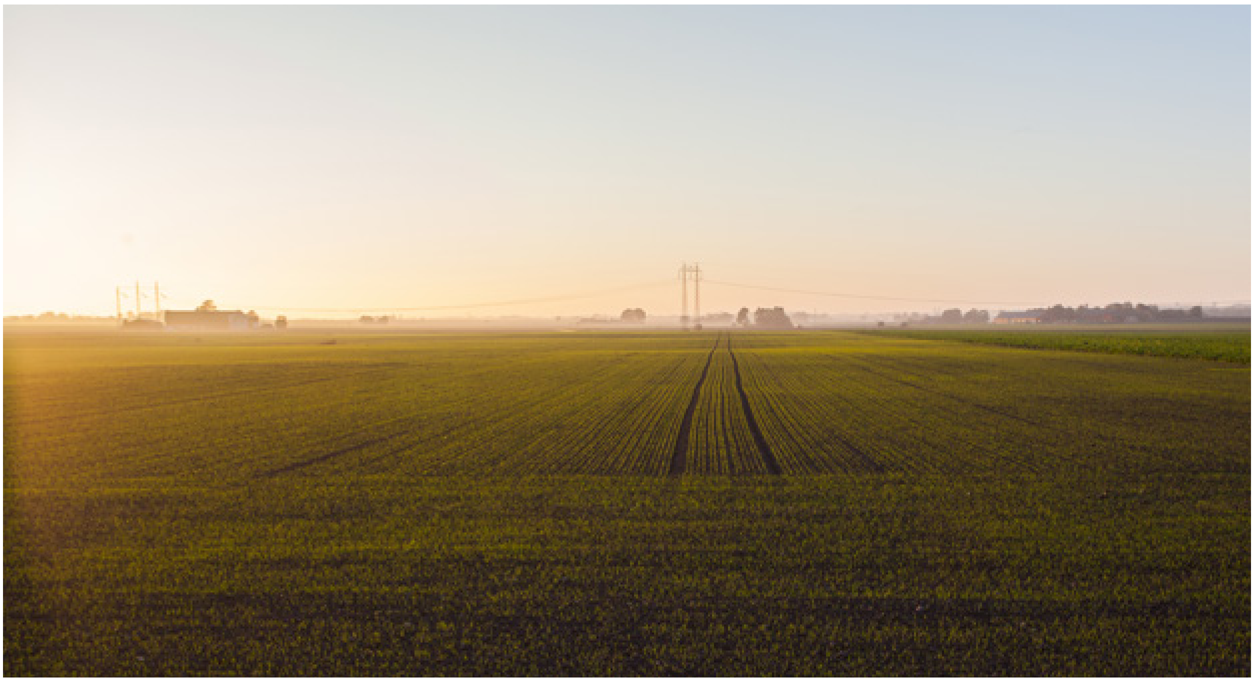
A group of researchers lead by Anna-Karin Kolseth and Martin Weih have written a review (that is to be published during the spring of 2015) that summarizes the current state of knowledge about the trait-specific effects of GMOs on ecosystem processes. They conclude that there is little evidence that the effects of GMOs on ecosystem processes differ from those of organisms modified using conventional methods, but there are significant knowledge gaps.

GMOs have been used in agriculture for three decades, but little is known about their trait-specific effects on ecosystem processes. Examples of GM traits introduced to date include pest resistance and herbicide tolerance in crops, increased growth rate in fish and livestock, and improved nitrogen-fixation capabilities of soil microbes, and many other traits are under development.

Anna-Karin and colleagues show that most of the effects of GMOs on ecosystem processes identified to date are indirect and are mostly the result of changes in management strategy rather than a direct effect of the GMO as such. Conflicting results on the performance and effects of GMOs are frequently reported, especially with regard to effects on crop yield and impacts on soil organisms. This is partly because the studies use methods with different levels of resolution, but also because many of the effects seem to be highly context-dependent.

Biotechnology offers the possibilities to incorporate new traits into organisms and provides a unique set of tools for gaining insights into the links between traits and ecosystem processes. Different traits can affect ecosystems both directly and indirectly, but studies linking specific traits to ecosystem processes at the field scale and over longer time scales are rare.

Kolseth A-K., D'Hertefeldt T., Emmerich M., Forabosco F., Marklund S., Cheeke T.E., Hallin, S., & Weih M. Influence of genetically modified organisms on ecosystem processes and implications for natural resource management. Submitted.



There are still knowledge gaps on how different traits affect the ecosystem processes, regardless of whether the traits have been introduced by genetic modification or not. Most of the effects are indirect and results from changes in management strategies.

GM crops, the hubris argument, and the nature of agriculture

Contact: *Payam Moula, moula@kth.se*

Thoughts about human relations with nature and our place in the world play a central role in environmental ethics. In a recently published essay, Payam Moula (KTH, Royal Institute of Technology) investigates the moral status of agricultural biotechnology and, more specifically, genetically modified (GM) crops by employing the hubris argument.

The old notion of hubris, given to us by the ancient Greeks, provides a narrative from which we can understand technology and ourselves. The strong, persuasive power of narratives in ethics and politics has been acknowledged and can be traced as far back as Plato.

Several authors have claimed that to engage in agricultural biotechnology is to exhibit arrogance, hubris, and disaffection. Ronald Sandler offers us an understanding of hubris that he claims gives us a reason and a presumption against the use of GM crops. At the core, his argument is that biotechnology falls within the tradition of manipulating and dominating our environment, and because this tradition has caused many of our current problems, relying on further manipulation and domination in the form of technological solutions would be hubris.

"Several authors have claimed that to engage in agricultural biotechnology is to exhibit arrogance, hubris, and disaffection."

Payam argues that Sandler's hubris argument fails for several reasons: 1) Sandler and many others fail to have a proper understanding of agriculture as an inherently technological practice that is radically different from "nature"; 2) the notions of control and manipulation that are central to the concept of hubris are difficult to understand and to use in the context of agriculture; 3) trying to establish a prima facie reason against GM crops runs into serious difficulty because many GM crops are profoundly different from each other; and 4) even if we accept Sandler's argument of hubris, it actually plays no role in the reasoning and evaluation of the moral status of different GM crops.

In the essay, Payam provides a second interpretation of Sandler's argument that does not imply that we have reasons to oppose GM crops per se, but rather that when we choose a strategy for meeting our agricultural challenges we cannot rely on GM crops as "the solution". Payam's interpretation of the argument might provide us with insights for how GM crops are to be used as a part of an overall strategy, but the argument does not succeed in establishing a presumption against their use.

Moula, P. 2015. GM Crops, the hubris argument and the nature of agriculture. *Journal of Agricultural and Environmental Ethics* 28: 161-177

Is agricultural biotechnology a form of hubris? And how does the concept of hubris apply to agriculture in general?

The dominance of the private sector in GM crop research and development, and regulations that prevent poor farmers from re-using seeds can hinder positive social impacts of GM crops.

Social impacts of GM crops in agriculture

Contact: *Klara Fischer, Klara.fischer@slu.se*

During 2014, a group of researchers came together in the synthesis project (CP6) to perform a systematic literature review of published research on the social impacts of GM crops in agriculture. The importance of addressing social impacts for meeting sustainable development is getting increased attention worldwide. Ending poverty, increasing wellbeing, and reducing inequality are all central aspects in the United Nations' new sustainable development goals. There is vivid debate in society at large as well as within the research community regarding whether or not the adoption of GM crops can contribute to meeting such goals. Conflicting views are also present in the scientific literature that they reviewed.

Preliminary results show that studies on economic aspects, studies on Bt cotton (insect resistant GM cotton), and studies with a focus on developing countries currently dominate the literature. The review also found that two important reasons for the conflicting views within research regarding whether or not GM crops can have positive social impacts on agriculture are that most studies have focused on a limited spectrum of social impacts and that studies focusing on different impacts come to different conclusions. Studies focusing on economic aspects are, in general, more positive to GM crops, whereas studies addressing aspects of access, distribution, and cultural heritage present a more negative picture regarding the possibility of GM crops having positive social impacts. Important barriers for reaching positive social impacts highlighted in the literature are the dominance of the private sector in GM crop research and development and regulations that prevent poor farmers from re-using seeds. The economic studies currently dominating the literature seldom address these aspects.

This review by Klara Fischer, Elisabeth Ekener Petersen, Karin Edvardsson Björnberg, and Lotta Rydhmer is to be submitted during the spring of 2015.

The 1000 bull genomes project

Contact: *Dirk Jan de Koning, dj.de-koning@slu.se*

Animal breeding is a long-term, multi-step process, and for successful breeding it is important to study the genetic background of different traits. To what extent does the variation in a trait between individuals depend on the effects of various genes? How do different traits relate to each other, and to what extent are such relationships explained by the genes? Based on trait records, animal pedigrees, and knowledge of the genetics of different traits, each animal's breeding value can be estimated. In the next step, the best animals are selected to become parents.

The cow genome consists of about 22,000 genes and a huge amount of potential markers, so-called "single nucleotide polymorphisms" (SNPs). Each SNP consists of a single point in the DNA sequence where the nucleotide is variable between individuals. Most recent studies report more than 25 million of such SNPs in the cattle genome.

Most traits that are important for animal production have a quantitative genetic background in which many genes, each with a very small effect, influence the final result. However, some gene variants have moderate to large effects, and such variants could be targets for direct selection. A first attempt to include DNA information was through so-called "marker-assisted selection" (MAS). In MAS, individual DNA markers are selected because of their proven effect on relevant traits, but the technique is time consuming and expensive. More recently, genomic selection has been introduced as an alternative to MAS. In genomic selection, no prior selection is made among markers and a very large number of markers (up to hundreds of thousands) across the genome are used to evaluate the breeding potential of selection candidates.

In the first step of genomic selection, a large number of animals, the so-called reference population, are "genotyped", i.e. their DNA is analysed to see whether they have A, T, C, or G for a large number of SNP markers. These animals are also "phenotyped", which means that their traits of interest are recorded. Using advanced statistical models, the phenotype and genotype data are combined to estimate how the genotype data can be used to predict the genetic merit of individuals.

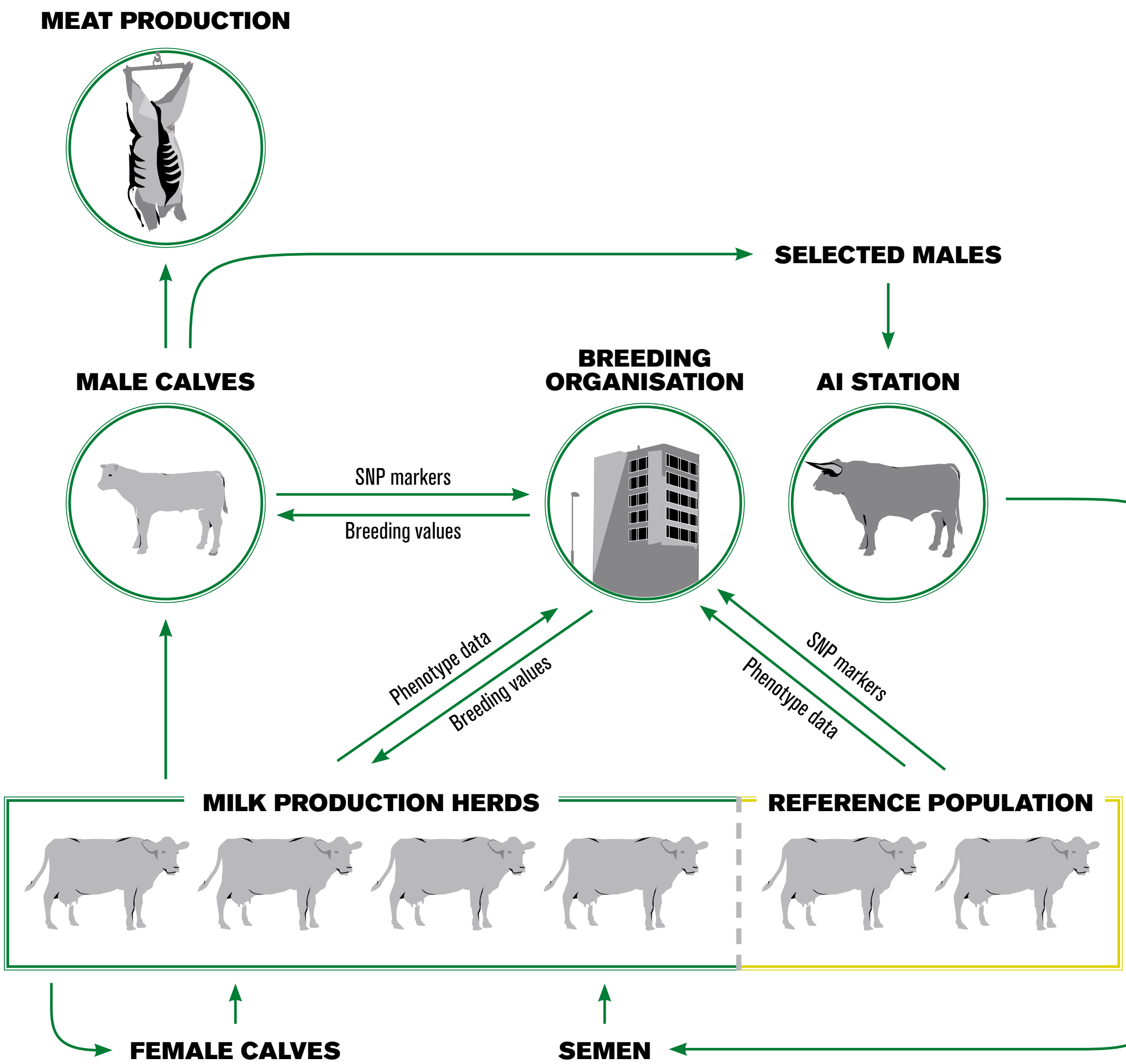
In the second step of genomic selection, animals from the next generation, the selection candidates, are genotyped for the same panel of markers. Using the prediction formulas from the reference population, genomic breeding values are estimated for these selection candidates. In this way, young, genotyped animals can be selected based solely on their SNP marker information even though they have no trait records. With this approach, bulls can get an accurate breeding value and be selected for breeding as soon as they are born. Previously, it took 6 years before a bull got an accurate breeding value because one had to wait until milk yield and other records became available from at least a hundred daughters (see illustration).

"bulls can get an accurate breeding value and be selected for breeding as soon as they are born"

The accuracy of the genomic breeding value generally increases with increasing numbers of reference individuals and increasing numbers of markers, but genotyping is expensive. Some bulls are genotyped with as many as 700,000 SNPs, but most bulls are genotyped with 50,000 SNPs. Only a small proportion of the cows are genotyped, usually with 10,000 SNPs or fewer.

With the aim of improving the quality of genomic breeding values in the Swedish Red breed, Mistra Biotech researchers led by Dirk Jan de Koning have sequenced the whole genomes of 16 bulls chosen because they are ancestors to many animals in the population. A further 9 bulls have been identified and are lined up for being sequenced in 2015. These 25 bulls are all part of the international 1000 Bull Genomes Project where a database of sequenced key ancestor bulls of 15 breeds is being built. The project is an example of researchers and geneticists in industry realizing that pooling of resources and sharing of data are crucial to delivering the promises of genome sequencing.

The whole genome sequence data from the 25 bulls and other bulls in the 1000 Bull Genomes Project



The figure illustrates a dairy cattle breeding programme with genomic selection. The breeding organisation is the hub where all information is stored and genetic evaluation is performed. In the herds, most female calves are raised, inseminated and used for milk production after calving. Most male calves are raised for meat production, but the best ones are moved to an artificial insemination (AI) station where semen is collected and distributed to all herds. Phenotype data on milk yield, reproduction, health etc. are recorded on all cows. In addition, some cows are "genotyped" to get data on SNP markers. These cows are called the reference population. Phenotype data and SNP markers are combined to predict breeding values of individual animals. Thus genotyped male calves can be evaluated based on their SNP markers and the best are selected to become AI bulls.

will be used for "imputation". Imputation is a way to use information from related animals that have had their genomes sequenced to fill in missing genetic information on animals that are genotyped with only a few markers. Dirk-Jan and colleagues use genetic information from the 1000 Bull Genomes database and apply computational tools to fill in information on missing genotypes of Swedish Red cows that have been genotyped with a small number of markers. In theory, the entire genome can be "filled in", but for a start they have been focusing on chromosome regions known to influence traits of economic importance, for example, calving difficulties and milk quality. Milk quality is of special interest for the Swedish Red breed because some cows give milk that does not coagulate and thus is useless for cheese production. Dirk-Jan and colleagues imputed sequence data from the 1000 Bull Genomes Project into a population where the cows had been genotyped with 800,000 SNP markers. They could identify several mutations important for milk production, and this shows the potential of whole genome sequencing when the costs are shared in an international collaboration.

For a recorded presentation on the 1000 bull genomes project please see: https://asas.confex.com/asas/WCGALP14/webprogram/Paper10441.html

Consumers' unconscious decision-making

Contact: *Carl-Johan Lagerkvist, carl-johan.lagerkvist@slu.se*

What influences people's choice in buying or not buying a product? Is it attitudes and goals that we have formed based on information that we have received and incorporated into our minds, or is it features of the products, the labels, and the context that stands out in the moment when we see and encounter the product that lead us to our decisions? Or is it a combination of these aspects, and if so, what do these dynamics look like? Is it possible that our first impressions are overtaken by our attitudes? Do we choose according to our immediate liking and disliking, or according to how we analytically think?

The food products we purchase have a number of labels and much information on the packages, and in the EU all food items that contain one or more ingredients that consist of more than 0.9% GMO have to be labelled. But how does the consumer view the packaging of food, does he or she notice the information and labelling of food such as health claims and environmental aspects? And how is his or her choice as a consumer affected by this information?

Through an eye-tracking study, Jacob L. Orquin and Carl-Johan Lagerkvist have tried to understand the unconscious mind that governs and rules consumer behaviour.

In cognitive psychology, one differentiates between the top-down approach and the bottom-up approach. The top-down approach includes more deliberate ways of thinking where one's attitudes and attention play a role. If one likes or dislikes something, one is more likely to observe it. But there is also the bottom-up process, which is rapid and automatic. This is governed by the unconscious mind, and in this case one tends to pay attention to what stands out. We then automatically filter out if what we have in visual focus is relevant or not. An object that stands out can attract attention and eye movements irrespective of its relevance to current goals. It is assumed that the top-down and bottom-up processes interact, but little is known about which process dominates at what time during a decision-making situation. However, it is known that the bottom-up effect tends to be short-lived, and an unresolved question has been at what point the eye movement process shifts from being driven by bottom-up processes to being driven by top-down processes.

The combination of the top-down and bottom-up indicates an interaction process between the two perspectives. These two systems operate together and to some extent are very much dependent on each other, however, it is easy to forget that this bottom up process exists – and when making a decision and that these two aspects are weighed together.

The research conducted within this project seeks to understand how the top-down and bottom-up processes interact when applied to the consumer choice of a GM food product. This research contributes with knowledge about how these processes operate with regard to a controversial technology. The findings suggest that people, when exposed to positive information and highly noticeable labelling, can be induced to choose a GM product, or they can be scared off if negative information about the technology is emphasized. When it comes to biotechnology information, consumers are more than likely to follow the societal discourse for the technology – we get the consumer response that we desire by formulating the information about the technology in a particular way. The effect of the negative framing is stronger than the impact on choice from a positive framing. However, and most importantly, this research shows that when people are not presented with a positive or negative information frame, they do not notice the label.

"when people are not presented with a positive or negative information frame, they do not notice the label"

In general, people are more "loss averse" than "gain seeking", and they pay more attention to negative outcomes than to positive because the negative

outcomes can be more dangerous. Moreover, after a while, there can be a learning effect so that people react differently to a new label. However, both the top-down (as expected) but also the bottom-up process (not as expected) continue to be active over the course of the choice process. Thus information, as well as label design, needs to be continuously updated – there is no "once and for all" strategy that would work in the long run.

Orquin, J.L., & Lagerkvist, C-J. Effects of salience are both short- and long-lived. Under review.

Media reporting on GMOs: A cross-Atlantic analysis

Contact: *Konstantinos Karantininis, Karantininis.Konstantinos@slu.se*

Different regulations about the approval of biotechnology and GMOs between the USA and Europe have been controversial for decades. Although there is broad scientific coverage of possible causes for this divergence, little is known about the role that popular media play in the related political discourse. Lena Galata, Konstantinos Karantininis, and Sebastian Hess analysed the media coverage of biotechnology topics in the USA and UK from 2011 to 2013 by examining two leading newspapers, The Washington Post and The Guardian. The two newspapers differed in their intensity of reporting on GMO issues but were alike in their content about GMOs. On both sides of the Atlantic, the central actors were scientists and NGOs arguing mostly in the field of the agricultural sector. The researchers found the debate to be locked in a stalemate of potential risks against potential benefits, with neither of the two positions clearly dominating the discourse.

Galata, L., Karantininis, K., & Hess, S. 2014. Cross-Atlantic differences in biotechnology and GMOs: A media content analysis, In: C. Zopounidis *et al.*, (Eds.), *Agricultural cooperative management and policy.* (pp: 299-314). Cham: Springer International Publishing.

Breeding for food security

Mulatu Geleta Dida's interest in biology started while he was a high-school student. He grew up in the Bale highlands in Ethiopia and earned his MSc in Biology at Addis Ababa University. After working at different teaching institutions, he joined the Ethiopian Biodiversity Institute (IBC) where he had the opportunity to analyse genetic variations in different crop species. This work continued when he obtained a PhD position at SLU.

– Working with genetic variation in crops made me realise the need for conservation of genetic resources not only for the plant breeding of today but also as security and protection against unforeseeable events in an uncertain future.

In 2007, he obtained his PhD in Genetics and Plant Breeding. Since then, he has been working at SLU in Alnarp as a researcher.

– I have a strong interest in plant breeding because it can contribute to sustainable food security. While working at SLU, I, together with my colleagues, developed self-compatible lines of noug (*Guizotia abyssinica*) (noug is normally a strictly cross-pollinated plant) for the first time in the cultivation history of the crop along with increased oil content and improved oil quality. The success in noug inspired me to take on the challenges of domesticating and breeding field cress (*Lepidium campestre*) within the Mistra Biotech programme.

At this early stage of domestication of field cress, Mulatu and his colleagues are focusing more on the major "domestication syndrome" traits that clearly differentiate crops from their wild relatives. They are using conventional plant breeding methods such as selfing, intra- and inter-specific hybridizations, and backcrossing. The results on traits like seed yield and pod-shatter resistance are looking very good. The domestication of the major crops we grow today has taken thousands of years, and even today, domestication of a new crop is generally a long-term project, but Mulatu is convinced that the process can be sped up significantly.

– The progress made so far and the rapid advances in plant genomics and efficient use of genomic tools for marker-aided breeding suggest that fast-track domestication of field cress is possible.

In line with this, the researchers are working toward developing genetic maps that can be used to select individuals with the best specific traits based on their genetic makeup. They are also using genomic selection – a method where selection is based on molecular markers across the whole genome of an organism.

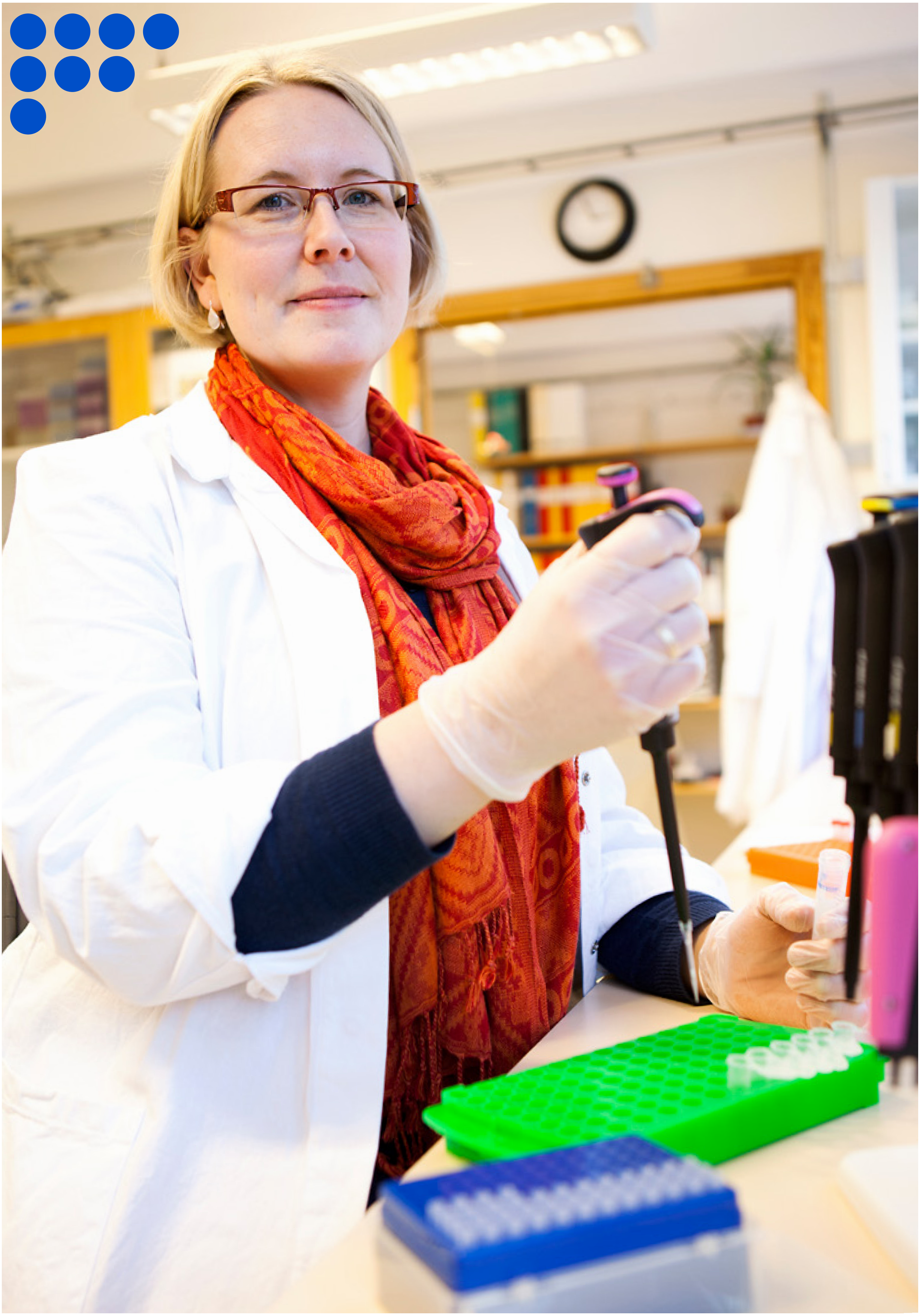
– Field cress is an excellent plant to work with because it has high potential as a new oil crop and as a cover crop. Because it is biennial, it provides higher carbon storage and better soil and water management compared to annual crops. But it would be even better if it were a perennial crop, something we might achieve through crossings with closely related perennial species.

Mistra Biotech is the first multi-disciplinary research program that Mulatu has been involved with, and it has provided him the opportunity to do what he likes the most, improving crops.

– It has given me a better understanding of how different disciplines can work together to have a bigger impact on society. I learned a lot about how the work of scientists, social scientists, economists, and ethicists is interconnected in addressing the demands of farmers, consumers, and society in general.

Read more about Mulatu's research on field cress in Geleta, M., Zhu, L.H., Stymne, S., Lehrman, A., & Hansson, S.O. 2014. Domestication of *Lepidium campestre* as part of Mistra Biotech, a research programme focused on agro-biotechnology for sustainable food, in Batello *et al.* (Eds.) *Perennial crops for food security.* Proceedings of the FAO expert workshop, Rome, Italy, 28-30 August 2013 (pp. 141-147). FAO, Italy.

« Mulatu Geleta Dida is a researcher at the Department of Plant Breeding at SLU in Alnarp and engaged in CP1 in Mistra Biotech.



Ecologist working on the gene level

Anna-Karin Kolseth grew up in Töre, a small village in northern Sweden, where forestry and the iron industry historically have had a large impact on society. These are still important industries for the area, although nowadays they employ fewer people. Being part of a community where natural resources are important stimulated Anna-Karin's interest in the relationship between the conservational values of nature and nature's production values.

– That, together with my fascination for plants, is the reason why I choose to study ecology, and why I do research on agricultural production.

Anna-Karin moved to Uppsala to study, and she obtained a master's degree in plant ecology from Uppsala University followed by a PhD in molecular ecology at Uppsala University/Södertörn University. The focus of her thesis was population genetics and conservation biology, and she worked with the annual plant eyebright (*Euphrasia stricta*) that has strong connections to the traditional agricultural landscape. The opportunity to do a post-doc on annual weeds led her to the Department of Crop Production Ecology at SLU, where she now has a research position studying plant pathogens and weeds with a focus on crop protection. But what is her role in Mistra Biotech?

– I am working on a literature study in the synthesis project (CP6) together with a number of researchers from different scientific areas (see page 25). The study has resulted in a review paper where we look at the ecological influences of GMOs in agriculture, including GM plants, animals, and microorganisms. We have focused on different ecological processes such as nutrient cycling, carbon sequestration, loss/gain of biodiversity, etc. Agriculture and forestry benefit from these processes, but they also interact with them, for example, depending on which crop is used in the production system.

Anna-Karin thinks that their work can be useful for policy-makers and society because the review compiles knowledge on GMOs and their effects on ecosystems.

– The approach of studying ecological processes is rather novel, so we provide new information. It is also important that we have identified knowledge gaps that need to be filled.

One knowledge gap that has been filled is Anna-Karin's own, regarding GMOs.

– Although I've been in contact with GMOs before, I felt that my knowledge was too shallow for a scientist in crop production, and when I got the chance to spend more time exploring the subject I took it. The project also increased the size of my network because I got to meet and collaborate with new colleagues.

« Anna-Karin Kolseth works as a researcher at the Department of Crop Production Ecology at SLU Ultuna and is engaged in CP6 in Mistra Biotech.

Lotta Rydhmer explaining animal genetics and breeding at the Mistra Biotech-day for high school students April 1.

Student checking out the education info-material from SLU.

Activities

11-15/1 "Genome wide association using imputed sequence data in dairy cattle with the 1000 bull genomes project data set" by D.J. de Koning *et al.*, was presented at the *Plant & Animal Genome XXII Conference* in San Diego. At the same conference DJ and F. Lopes Pinto (*et al.*), presented "Oligoreef – Generation of primers for complex polymerase chain reactions".

19-20/1 A. Lehrman (and others) met with Mikayla Keen, communicator at CSIRO, and visited Swedish Radio, Mistra, and the Gene Technology Advisory Board.

22/1 S.O. Hansson participated in a panel discussion at the launching event of "Growing Voices" online platform organised by EuropaBio in Brussels.

23-25/1 P. Sandin and S.O. Hansson gave talks at the workshop *New Technologies and Social Experiments,* Technical University of Delft, Netherlands: "Responsible social experimentation – fiddling with a trope or a way forward?" and "Experiments – Why and how?".

6/2 S. Stymne talked about GMO and Mistra Biotech at a symposium for chicken producers arranged by Stiftelsen Svenska Kycklinguppfödare and SLU.

9-13/2 Oral presentations by U. Ganeteg "Root uptake of amino acids at naturally occurring concentrations", H. Svennerstam "Root-shoot allocation of biomass depends on nitrogen source", and S. Jämtgård "Organic nitrogen in agricultural soil". *The International Workshop on Organic Nitrogen and Plant Nutrition – from Molecular Mechanisms to Ecosystems*. Centro Stefano Franscini, Switzerland.

20/3 P. Sandin gave a presentation "Animal feed – ethical aspects" at the Swedish Association of Veterinary Feed Control.

1/4 Mistra Biotech-day for high school students. Lectures by Studentpoolen, J. Sundström, L. Rydhmer, K. Koch, A. Pakseresht, P. Sandin, T. Jansson, K. Jäderkvist, and A-K Kolseth.

13/5 Forskningens samhällsansvar Kungl. Fysiografiska Sällskapet in Lund. S. Stymne gave a talk on "Är motståndet mot gentekniken på växter ett brott mot mänskligheten?".

16/5 KSLA seminar: *A changing climate – how does it affect Swedish possibilities for green economic growth?* L. Rydhmer presented Mistra Biotech in a talk "Breeding plants and animals for mitigation and adaption to a changed climate in the Nordic countries".

21/5 *GMO GenEtik - Hur skapar vi framtidens mat?* at Lund University. P. Sandin was the moderator and S. Stymne gave a short talk and took part in the debate. Organised by PlantLink and Alnarp Student Union.

23/5 Mistra Biotech workshop arranged by CP5: *Regulatory challenges for agricultural biotechnology in the EU*. S.O. Hansson and Carl-Johan Lagerkvist gave presentations.

2/6 Visit to SLU Uppsala by the Department of International Trade Policy of the Swedish Foreign Ministry. A. Lehrman gave a presentation "GMO – forskning, framtid och farhågor".

4-6/6 K. Karantininis was a key-note speaker in the session "Integrating industry, academia and politics innovation agenda's to increase the sustainability and competitiveness of the European agrifood industry" at the *11th Wageningen International Conference on Chain and Network Management,* Capri, Italy.

24-25/6 Mistra Biotech symposium and workshop: *Breeding genetically modified animals for food production* arranged by CP2, 3 and 6.

25-27/6 S. Chatzopoulou presented the paper "The challenges of the transnational regulatory governance of the food chain standards" at the *5th European Community Studies Association Regulatory Governance Conference,* Barcelona, Spain

6-11/7 L.H. Zhu gave a talk “Development of a new oilseed crop *Lepidium campestre*”, and E. Ivarson presented a poster “Alteration of seed oil composition in *Lepidium campestre*” at the *21st International Symposium on Plant Lipids* at the University of Guelph, Canada.

17-22/8 D.J. de Koning participated at the *10th World Congress on Genetics Applied to Livestock Production*, where several of his project were presented.

9/9 A. Lehrman was invited speaker (on science journalism) at Sveriges Radio’s 40 year anniversary celebration of the radio show Vetandets Värld.

13/9 A. Lehrman gave a presentation on “GMO – forskning, framtid och farhågor” at the open house day at the Ecology Centre, SLU, Uppsala.

23/9 A. Lehrman gave a presentation on “GMO – forskning, framtid och farhågor” at the Faculty of Natural Resources and Agricultural Sciences-day, SLU, Uppsala.

25-27/9 S. Chatzopoulou presented the paper “The contested politics of the EU regulatory governance of GMOs” at the *Danish European Community Studies Association’s Annual Conference*, Aarhus University, Denmark.

13-15/10 The Mistra Biotech meeting, an event with over 40 researchers from the programme and invited speakers participating (internal meeting).

15/10 P. Sandin was invited to talk on “The adverbial analysis of precaution” at the *Helmholtz Research School on Energy Scenarios*, Karlsruhe Institute of Technology Autumn School, Karlsruhe, Germany.

4/11 A. Lehrman gave a presentation on “GMO – forskning, framtid och farhågor” at Rotay Glunten, Uppsala.

4/11 A. Lehrman held a lecture on “Science and society – why researchers are not always viewed as the good guys”, with emphasis on the GMO issue, as part of the course “Research Ethics for PhD Students”.

12/11 C.J. Lagerkvist gave a presentation on consumer attitudes regarding the use of biotechnology in the agriculture and food sector at the Gene Technology Advisory Board, Stockholm.

17/11 J. Sundström and L. Rydhmer were invited to Kungliga Vetenskapssamhället i Uppsala to initiate a discussion on “Bioteknologi i framtidens växtodling – tro och vetenskap”.

27/11 Mistra Biotech lunch seminar *GM-food – arguments on naturalness and authenticity* with philosopher Helena Siipi (University of Turku, Finland), SLU, Uppsala.

28-31/11 L.H. Zhu gave a talk “Genetic improvement of a new oilseed crop *Lepidium campestre*” at the *10th International Symposium on Biocatalysis and Agricultural Biotechnology*, I-SHOU University, Taiwan.

10/12 L.H. Zhu gave a presentation about her research, foremost about new breeding technologies, at the Gene Technology Advisory Board, Stockholm.

Christopher Ansell giving his presentation on regulatory styles in food safety in the EU and the US at the Mistra Biotech workshop Regulatory challenges for agricultural biotechnology in the EU, on May 25.

Helen Sang talking about GM techniques applicable for animals at the Mistra Biotech symposium Breeding genetically modified animals for food production on June 24.

Mistra Biotech-selfie at the annual programme meeting in October.

Karin Edvardsson Björnberg and Charlotta Zetterberg presenting their project that compares how deliberate releases of GM and non-GM crops (eg. a seed imported from another EU country) are governed by Swedish law.

Payam Moula giving a summary of his group's thoughts about the continued research in Mistra Biotech.

Group discussions on how we will continue the research in the programme. On the right, Lars Sandman (board member) is contributing to the complex web of research topics.

Mistra Biotech in the media

NEWSPAPERS/WEB

UNT (7/1) “Sida sprider skrönor”

Land Lantbruk & Skogsland (8/1) “Skattepengar till fältförsöksvandaler”

UNT (12/1) “Omvärlden styrs inte av Sida”

UNT (13/1) “Genteknik måste ifrågasättas”

Svea Jord & Skog (27/2) “Legitimt att bortse från fakta i GMO-debatten”

ATL (17/3) “GMO-forskning i fara”

SVT Nyheter (17/3) “Svensk GMO-forskning läggs ner”

SVT Nyheter (17/3) “Så här tycker forskarna om GMO”

Fjäderfä (24/3) “GMO – en vision om framtiden”

SVT Nyheter (25/4) “Forskare vill lätta på GMO-regler”

KSLA Nytt & Noterat (19/6) “Vad betyder klimatförändringarna för grön ekonomisk tillväxt?”

SvD (23/6) “LRF efter super-broccolin: ’Behövs ny lagstiftning’”

SvD (16/8) “Minskat motstånd mot GMO”

ATL (16/8) “GMO-motstånd luckras upp”

Marie Curie (2/9) “Parallell vetenskap och grön ideologi – ett hot mot demokratin”

Journalisten (9/9) “Granska makt och pengar inom forskningen”

Science Newsline (18/9) “Want to link genes to complex traits? Start with more diversity”

Science 2.0 (18/9) “There is no magic genetic bullet for complex traits, but here are 18 approaches”

Bright Surf (19/9) “Want to link genes to complex traits? Start with more diversity”

MNT (22/9) “Mapping complex trait genes in multiparental populations”

The Wall Street Journal (28/10) “The warped world of parallel science”

Jordbruksaktuellt (29/10) “DEBATT – Aktivister skadar demokratin”

ATL (29/10) “SLU-forskare ser aktivister som hot mot demokratin”

C – en idétidskrift om cerealier (nr 4 2014) “Låt egenskaperna och inte tekniken styra”

NewsVoice (9/12) “Det handlar om hur man anvander tekniken inte om tekniken i sig”

RADIO

Vetenskapens värld (17/3) “Striden om genmodifierade grödor”

SR, Vetenskapsradion (18/3) “Resistent skalbagge i genmodifierad majs”

SR, Vetandets värld (28/4) “Mendel och molekylärgenetik”

SVT, Kodjos kval (29/4)

SR, Vetandets värld (20/5) “Genförändrad mat – hot eller möjlighet?”

Publications

SCIENTIFIC

Abera Desta, Z., & Ortiz, R. 2014. Genomic selection: genome-wide prediction in plant improvement. *Trends in Plant Science* 19: 592-601

Alexandersson, E., Jacobson, D., Vivier, M.A., Weckwerth, W., & Andreasson, E. 2014. Field-omics – understanding large-scale molecular data from field. *Frontiers in Plant Science* 5 DOI: 10.3389/fpls.2014.

Chatzopoulou S. 2014. Unpacking the mechanisms of the EU 'throughput' governance legitimacy – the case of EFSA. *European Politics and Society*. DOI:10.1080/23745118.2014.974312

Chawade, A., Alexandersson, E., & Levander, F. 2014. Normalyzer: A tool for rapid evaluation of normalization methods for omics data sets. *Journal of Proteome Research* 13: 3114–3120

Geleta, M., Zhu, L.H., Stymne, S., Lehrman, A., & Hansson, S.O. 2014. Domestication of *Lepidium campestre* as part of Mistra Biotech, a research programme focused on agro-biotechnology for sustainable food, in Batello, C., Wade, L., Cox, S., Pogna, N., Bozzini, A., & Choptiany, J. (Eds.) *Perennial crops for food security*. Proceedings of the FAO expert workshop, Rome, Italy, 28-30 August 2013 (pp. 141-147). FAO, Italy.

Moula, P. 2015. GM Crops, the hubris argument and the nature of agriculture. *Journal of Agricultural and Environmental Ethics* 28: 161-177

BOOKS/BOOK CHAPTERS

Galata, L., Karantininis, K., Hess, S. 2014. Cross-Atlantic differences in biotechnology and GMOs: A media content analysis, In: Zopounidis C., Kalogeras, N., Mattas K., van Dijk G., & Baourakis G. (Eds.), *Agricultural cooperative management and policy*. (pp: 299-314). Cham: Springer International Publishing.

Hansson, SO. 2014. Agricultural Biotechnology for Health and the Environment, in M.R. Ahuja, and K.G. Ramawat (Eds.) *Biotechnology and Biodiversity.* Springer, ISBN 978-3-319-09381-9

Hansson, S.O. 2014. Food Labelling. In: Thompson, P.B., Kaplan, D.M., Millar, K., Heldke, L., Bawden, R. (Eds.), *Encyclopedia of Food and Agricultural Ethics*. Springer

Hansson, S.O. 2014. Food Risks. In: Thompson, P.B., Kaplan, D.M., Millar, K., Heldke, L., Bawden, R. (Eds.), *Encyclopedia of Food and Agricultural Ethics*. Springer

Hansson, S.O. 2014. Occupational Risks in Agriculture. In: Thompson, P.B., Kaplan, D.M., Millar, K., Heldke, L., Bawden, R. (Eds.), *Encyclopedia of Food and Agricultural Ethics.* Springer

Lehrman, A. (Ed.). 2014. *Shaping our food – an overview of crop and livestock breeding*. Uppsala, SLU. E-book, ISBN 978-91-637-5757-0

Lehrman, A. (Ed.). 2014. *Framtidens mat – om husdjursavel och växtförädling*. Uppsala, SLU. ISBN 978-91-637-5758-7 (web), ISBN 978-91-981907-0-0 (print)

Board

MISTRA BIOTECH BOARD MEMBERS

Inger Andersson	Prev. Swedish National Food Agency
Bo Gertsson	Lantmännen Lantbruk
Joakim Gullstrand	Department of Economics, Lund University
Stefan Jansson	Department of Plant Physiology, Umeå University
Lars Sandman	School of Health Science, University of Borås
Johan Schnurer	Department of Microbiology, SLU
Harald Svensson	Swedish Board of Agriculture

Researchers

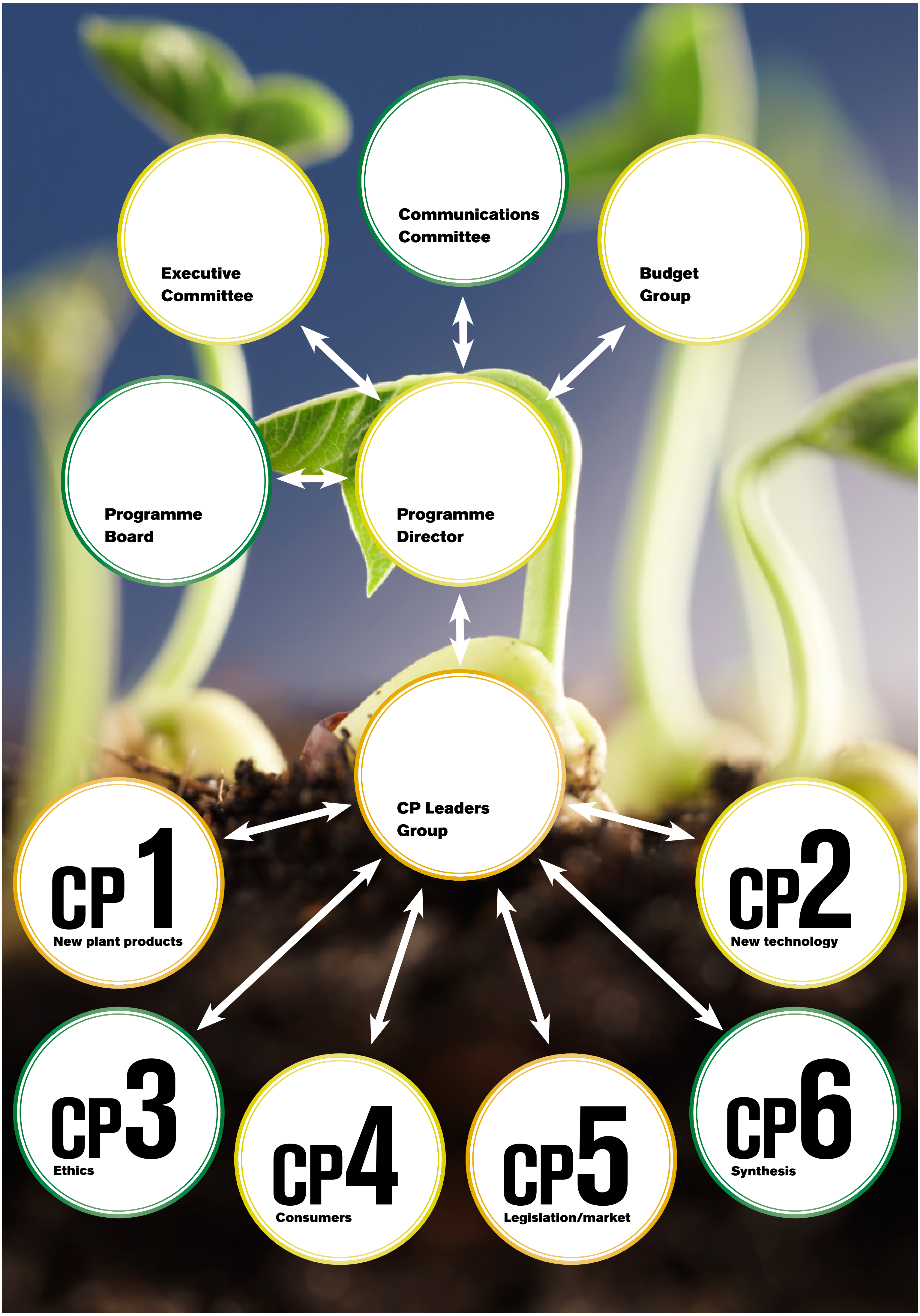
EMPLOYED AND ASSOCIATED RESEARCHERS

Name	Position	Department
CP1: Plant biotechnology for innovative products		
Alessandro Nicolia	Researcher	Plant Breeding, SLU
Camila Cambui	Post-Doc	Forest Genetics and Plant Physiology, SLU
Carolin Menzel	PhD student	Food Science, SLU
Emelie Ivarson	PhD student	Plant Breeding, SLU
Erik Andreasson	Deputy project leader	Plant Protection Biology, SLU
Henrik Svennerstam	Researcher	Forest Genetics and Plant Physiology, SLU
Iftikahar Ahmad	PhD student	Forest Genetics and Plant Physiology, SLU
Inger Åhman	Researcher	Plant Breeding, SLU
Kristine Koch	Researcher	Food Science, SLU
Lena Dimberg	Researcher	Food Science, SLU
Li Hua Zhu	Project leader	Plant Breeding, SLU
Mariette Andersson	Researcher	Plant Breeding, SLU
Mattias Holmlund	Research engineer	Forest Genetics and Plant Physiology, SLU
Mulatu Dida Geleta	Researcher	Plant Breeding, SLU
Nawaporn Onkokesung	Post-Doc	Plant Breeding, SLU
Roger Andersson	Researcher	Food Science, SLU
Samanthi Madawala	PhD student	Food Science, SLU
Sandra Jämtgård	Post-Doc	Forest Ecology and Management, SLU
Sten Stymne	Researcher	Plant Breeding, SLU
Torgny Näsholm	Researcher	Forest Ecology and Management, SLU
Ulrika Ganeteg	Researcher	Forest Genetics and Plant Physiology, SLU
CP2: Novel molecular breeding tools		
Aakash Chawade	Post-Doc	Immunotechnology, Lund University
Anna Johansson	Researcher	Animal Breeding and Genetics, SLU
Christina Dixelius	Researcher	Plant Biology and Forest Genetics, SLU
Dirk-Jan de Koning	Project leader	Animal Breeding and Genetics, SLU
Elisabeth Jonas	Post-Doc	Animal Breeding and Genetics, SLU
Erik Bongcam-Rudloff	Researcher	Animal Breeding and Genetics, SLU

Name	Position	Department
Fernando Lopes Pinto	Post-Doc	Animal Breeding and Genetics, SLU
Fredrik Levander	Researcher	Immunotechnology, Lund University
Jane Morrell	Researcher	Clinical Sciences, SLU
Lars Rönnegård	Deputy project leader	Animal Breeding and Genetics, SLU
Mulatu Dida Geleta	Researcher	Plant Breeding, SLU
Patrice Humblot	Researcher	Clinical Sciences, SLU
Rodomiro Ortiz	Researcher	Plant Breeding, SLU
Zeratsion Abera	Researcher	Plant Breeding, SLU
CP3: Ethics		
Helena Röcklinsberg	Researcher	Animal Environment and Health, SLU
Karin Edvardsson Björnberg	Project leader	Philosophy and History of Technology, KTH*
Payam Moula	PhD student	Philosophy and History of Technology, KTH*
Per Sandin	Deputy project leader	Crop Production Ecology, SLU
CP4: Consumer attitudes towards biotechnology		
Andreea Bolos	Forskningsassistent	Economics, SLU
Ashkan Pakseresht	PhD student	Economics, SLU
Carl-Johan Lagerkvist	Project leader	Economics, SLU
Jacob Lund Orquin	Post-Doc	Business Administration, Aarhus University, DK
Sebastian Hess	Researcher	Economics, SLU
CP5: Swedish competitiveness		
Jun Zhou	Post-Doc	Economics, SLU
Christopher Kevin Ansell	Researcher	Political Science, University of California, USA
Konstantinos Karantininis	Project leader	Economics, SLU
Luca Di Corato	Researcher	Economics, SLU
Natalia Montinari	Researcher	Economics, Lund University
Ranjan Ghosh	Post-Doc	Economics, SLU
Sevasti Chatzopoulou	Researcher	Society and Globalisation, Roskilde University, DK
Torbjörn Jansson	Researcher	Economics, SLU
CP6: AgriSA - Centre for agriculture and food systems analysis and synthesis		
Alessandro Nicolia	Researcher CP1	Plant Breeding, SLU
Anna Lehrman	Communications officer	Crop Production Ecology, SLU
Anna-Karin Kolseth	Researcher	Crop Production Ecology, SLU
Barbro Ulén	Researcher	Soil and Environment, SLU
Carl-Johan Lagerkvist	Project leader CP4	Economy
Charlotta Zetterberg	Researcher	Law Department, UU
Dennis Collentine	Researcher	Business and Economics Studies, Högskolan I Gävle
Dennis Eriksson	Researcher	Plant Protection Biology
DJ de Koning	Project leader CP2	Animal breeding and genetics
Elisabeth Ekener Petersen	Researcher	Sustainable Development, Environmental Science and Engineering, KTH*
Elisabeth Jonas	Post-Doc CP2	Animal Breeding and Genetics, SLU
Erik Andreasson	Researcher CP1	lant Protection Biology
Flavio Forabosco	Researcher	Animal Breeding and Genetics, SLU

Name	Position	Department
Helena Röcklinsberg	Researcher CP3	Animal Environment and Health, SLU
Henrik Eckersten	Researcher	Crop Production Ecology, SLU
Holger Johnsson	Researcher	Soil and Environment, SLU
Håkan Marstorp	Researcher	Soil and Environment, SLU
Jens Sundström	Researcher	Plant Biology and Forest Genetics, SLU
Karin Edvardsson Björnberg	Project leader CP3	Philosophy and History of Technology, KTH*
Klara Fischer	Researcher	Urban and rural development
Konstantinos Karantininis	Project leader CP5	Economics, SLU
Kristina Mårtensson	Researcher	Soil and Environment, SLU
Li Feng	Researcher	Economics, SLU
Li Hua Zhu	Project leader CP1	Plant Breeding, SLU
Lotta Rydhmer	Project leader	Animal Breeding and Genetics, SLU
Maren Emmerich	Post-Doc	Microbiology, SLU
Mariette Andersson	Researcher CP1	Plant Breeding, SLU
Martin Weih	Researcher	Crop Production Ecology, SLU
Mulatu Dida Geleta	Researcher CP1/CP2	Plant Breeding, SLU
Nils-Ove Bertholdsson	Researcher	Plant Breeding, SLU
Payam Moula	PhD student CP3	Philosophy and History of Technology, KTH*
Pernilla Tidåker	Researcher	Crop Production Ecology, SLU
Per Sandin	Researcher CP3	Crop Production Ecology, SLU
Per Åman	Researcher	Food science, SLU
Sara Hallin	Researcher	Microbiology, SLU
Sevasti Chatzopoulou	Researcher CP5	Society and Globalisation, Roskilde University, DK
Stefan Marklund	Researcher	Clinical Sciences, SLU
Sten Stymne	Researcher CP1	Plant Breeding, SLU
Sven Ove Hansson	Programme director	Crop Production Ecology, SLU & KTH*
Tina D'Hertefeldt	Researcher	Biology, Lund University
Tanya Cheeke	Researcher	Forest Mycology and Plant Pathology, SLU
Thomas Kätterer	Researcher	Ecology
Torgny Näsholm	Researcher CP1	Forest Ecology and Management, SLU

** Royal Institute of Technology (KTH)*



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Executive Committee
Budget Group
Programme Board
Programme Director
CP Leaders Group
CP1
New plant products
CP2
New technology
CP3
Ethics
CP4
Consumers
CP5
Legislation/market
CP6
Synthesis