SEFARI

Leading Ideas for Enhancing Crop Health

SRUC

Royal Botanic Garden Edinburgh

BioSS

Moredun

The Rowett Institute

The James Hutton Institute

Scottish Government
Riaghaltas na h-Alba
gov.scot

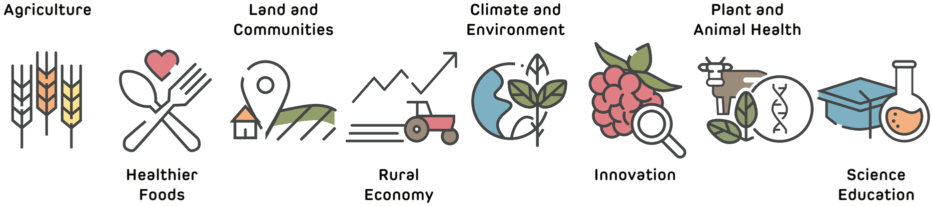
Leading Ideas on Crops: Sustainable Food Systems and Supply

The Scottish Environment, Food and Agriculture Research Institutes (SEFARI) is a collective of six research institutes, each with their own global capability, expertise and reputation.

The six institutes are:

- Biomathematics and Statistics Scotland
- James Hutton Institute
- Moredun Research Institute
- Rowett Institute
- Royal Botanic Garden Edinburgh
- Scotland's Rural College

SEFARI focuses its work under eight 'Leading Ideas'



This booklet highlights key research outputs from Scottish Government funded strategic research programme 2022-27 on sustainable food systems and supply. This includes research on sustainable food production from domestic agriculture through to sustainable and secure supplies of food, as well as supporting a safe and healthy diet. It provides elements of research relevant right through from farm to fork to contribute to the economy, people's livelihoods and the health of the nation.

One of the primary focuses is in developing resilient, high-quality crop, and food and drink industries that capture market value and contribute to Scotland's economy. There is also a focus on improving agricultural practices to develop a resilient, productive sector that is abreast of new and transformative opportunities.

Here we highlight examples of impact arising directly from the Strategic Research Programme and its crucial role in leveraging of further research funding to expand impact.

Contact us

www.sefari.scot

@SEFARIscot
#LeadingIdeas

info@sefari.scot

Introduction

The Scottish Environment & Agriculture Research Institutions' (SEFARI) research supports the UK's National Action Plan (NAP) for pesticide reduction, combining Artificial Intelligence, big data, and biology to revolutionise Integrated Pest Management (IPM) in Scotland. From forecasting potato virus risks to advancing biological alternatives to conventional pesticides, this work helps farmers target pesticide use while safeguarding yields and the environment. Underpinned by Scottish Government funding, this science-driven approach is reshaping pest management, ensuring sustainable farming and future-proofing Scotland's vital agricultural sector and thus its rural economy.

Work on Integrated Pest Management (IPM) supports the key actions of the recently published NAP for the Sustainable Use of Pesticides and is underpinned by vital strategic research funding from the Rural & Environment Science & Analytical Services Division (RESAS) of the Scottish Government and this in turn leverages significant additional funding from a range of sources. We collaborate globally whilst focusing on Scotland's ambitions, making use of big data, AI, and knowledge of pest and pathogen biology to reduce reliance on chemical pesticides while maintaining agricultural productivity and protecting the environment.

Arable farming contributes 85–90% of UK pesticide use. For example, in Scotland virtually all seed and ware potato crops were treated with fungicides in 2022, receiving on average 8 to 10 fungicide applications per season, primarily for the control of potato late blight caused by Phytophthora infestans. Pesticide use remains vital for crop production and whilst improper use risks resistance development and damage to the environmental, pesticide reduction strategies are not simple. For example, removal of an active ingredient from the market can increase applications of less effective alternatives and therefore increase uncertainty. Smarter management strategies and their implementation in practice are essential and applied research has a critical role in achieving these aims.

This booklet provides examples of our key research contributing to crop management and improved targeting of necessary pesticides. Some future priorities to meet this aim and to deliver to the NAP include:

- **Integration of epidemiological studies with an understanding of external influences** to identify weaknesses in the current cropping systems and propose control strategies for the future.
- **Underpinning Research**: to monitor and understand current and emerging pest and disease risks, to develop effective pesticide alternatives and improved crop genetics.
- **Enhanced Monitoring Systems**: to track emerging pesticide and host resistance and adjust practices accordingly in real time.
- **Promote IPM Adoption**: by working with stakeholders to test and demonstrate combinations of forecasting tools, resistant varieties, crop rotation, pesticides and biocontrol.
- **Incentivise Sustainability**: by rewarding growers for adopting IPM practices where these are practical.

Contact: Alison Lees – Alison.Lees@hutton.ac.uk

"From forecasting potato virus risks to advancing biological alternatives to conventional pesticides, SEFARI research helps farmers target pesticide use while safeguarding yields and the environment."

Pest & Disease Threats to Scottish Crops – an Evolving Situation

Informing crop production and protection

Contact: Alison Karley – Alison.Karley@hutton.ac.uk

youtu.be/XDvpsDR-09s

The sustainability of agricultural production in Scotland and globally is under pressure from a multitude of factors. Pests and diseases can cause important economic losses and threaten food security; an estimated 15-20% of the crops produced in Scotland is lost to pests and diseases annually.

The appearance of invasive pests and pathogens in Scotland is favoured by the changing climate, loss of crop protection chemicals, increasing resistance to pesticides, and high mobility and transport of people and products around the globe. A recent study funded by the Scottish Government funded Scottish Plant Health Centre, part of the Scottish Government's wider Strategic Research Portfolio of funding, identified a suite of plant pathogens and arthropod pests that could become established in Scotland through these routes and threaten the productivity of arable and horticultural crops.

To safeguard Scottish agriculture against these threats, SEFARI researchers are working with agricultural stakeholders to investigate the epidemiology and control of recent and emerging invasive pests and pathogens:

Spotted wing Drosophila was first detected in Scotland 10 years ago, and numbers have increased notably since. As the insect lays its eggs in unripe fruit, research has focussed on identifying raspberry and blackberry varieties that are less susceptible to egg laying and larval development. Machine learning has been used to characterise the landscape features and environmental conditions that favour pest establishment.

Aphid-vectored viruses have become more severe in Scotland due to the warming climate, loss of crop protection products and pest resistance. In potato crops, we are investigating whether alternative (non-insecticide) control products and companion cropping can reduce aphid abundance and increase the activity of their natural enemies. Additionally, we are investigating the prevalence of new virus variants and mechanisms of plant resistance. Our predictive models highlight where virus pressure is likely to be high from one season to the next so that growers and agronomists can take preventative actions.

The Power of Sequencing to Understand Plant Pathogen Populations

Tracking strains to inform disease management

Contact: David Cooke - David.Cooke@hutton.ac.uk

Plant pathogens exhibit variability in their ability to cause disease on specific crop plants. The deployment of disease resistance genes in crops places strong selective pressure on pathogens to adapt, leading to the emergence of resistance-breaking pathogen strains and severe crop losses. Similarly, use of crop protection chemicals can select for pathogen variants that are insensitive to specific active ingredients and lead to control failure.

Expanding knowledge of the pathogen proteins that are recognised by resistant plants or are the specific targets for control chemicals is providing opportunities to track the evolving pathogen genes, and thus traits, in field populations and improve disease management.

Advances in DNA sequencing technologies have enabled parallel sequencing of hundreds of pathogen genes. SEFARI scientists have sequenced genes of Phytophthora infestans, the potato and tomato late blight pathogen that is notorious for its role in the 1840s Irish potato famine. This rapidly evolving pathogen remains destructive today with management relying on a combination of host resistance and regular applications of fungicide.

Despite these strategies providing effective disease control for many years, strains that are insensitive to key fungicide ingredients or able to overcome host resistance are now appearing in the UK and continental Europe. By sequencing all the genes for known virulence proteins and chemical targets in contemporary UK populations of P. infestans, SEFARI scientists are gaining insights into how these key genes are evolving.

From the DNA sequence data, we are tracking specific mutations that condition fungicide insensitivity and defeat blight resistance genes in some potato varieties. This knowledge is directly informing the sustainable management of this devastating disease. Furthermore, our international expertise is also identifying and future-proofing against further pathogen incursions from beyond the UK borders.

Plant Protection Through Prediction - Forewarned is Forearmed

Contact: Pete Skelsey - Pete.Skelsey@hutton.ac.uk

Accurate prediction of crop pests and diseases is critical to food security and profitable production as it enables growers to make informed decisions and take preventative measures. Our ability to predict crop pests and diseases with precision is increasingly important as our food systems are threatened by the trifecta of climate change, evolving pest and pathogen populations, and the loss of efficacy, or withdrawal, of key crop protection products. SEFARI scientists are using big data and advanced modelling techniques to develop new tools to keep our growers forewarned and forearmed to deal with some of the major threats to our crops.

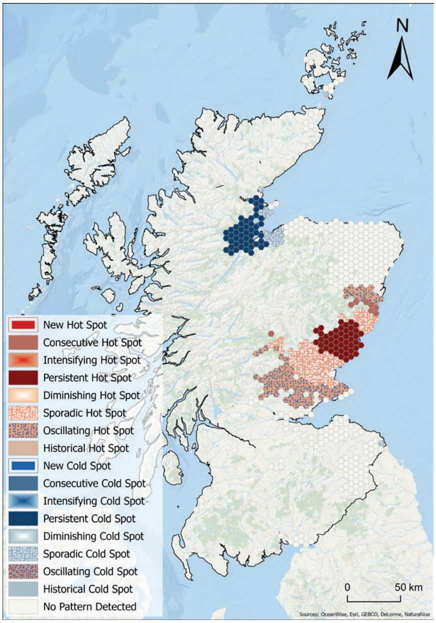
- Potato viruses. Warmer winters and the loss of insecticides makes management of aphid-borne potato viruses increasingly complex. Artificial Intelligence was applied to statutory crop inspection data to develop new national and local warning systems for forecasting the risk of potato virus Y (PVY) and potato leafroll virus which have been made available to the potato industry.
- Potato cyst nematodes (PCN). Scottish land is increasingly becoming infested with PCN. An AI-based tool developed from statutory soil testing data to predict PCN infestation in any location will provide predictions for areas not subject to compulsory testing, identify where new infestations are more likely to occur, and provide the information required to develop spatial management strategies.
- Barley diseases. Ramularia leaf spot and Rhynchosporium are the two major diseases affecting barley crops. Long-term datasets were analysed to quantify how environmental conditions and management interventions affect disease risk and to develop two robust forecasting systems. The models are being used internationally in major barley-producing countries.
- Late blight. New aggressive and fungicide resistant strains originating in mainland Europe constantly threaten Scottish potato crops. AI techniques were applied to samples collected from across Great Britain to develop a model for predicting the genotype of an outbreak. This complements our national late-blight monitoring efforts by providing predictions for unsampled crops and rapid alerts for the presence of resistance-breaking and fungicide-resistant strains.

youtu.be/d1mlUx2Nn9w

Landscape Epidemiology

Factors influencing epidemic patterns

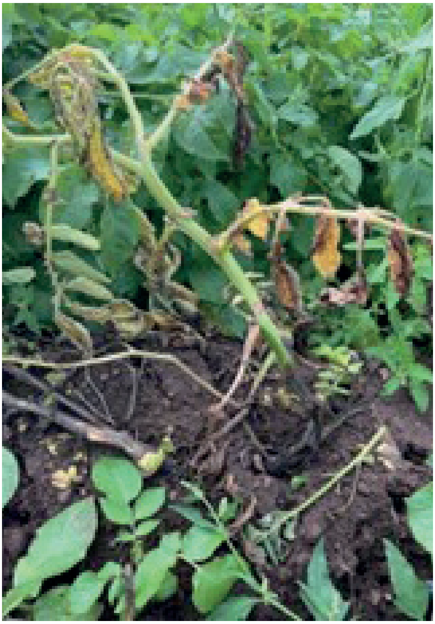
Contact: Pete Skelsey – Pete.Skelsey@hutton.ac.uk



A central challenge to studying plant disease epidemiology is the landscape dilemma: our empirical understanding of pests and diseases comes from small-scale laboratory, glasshouse, and field experiments, whereas epidemics and their management occur at the landscape-scale. Due to the challenges in conducting experiments at large spatial scales, landscape epidemiology has emerged as an important field of study that employs spatial approaches to investigate the distribution and determinants of epidemics.

SEFARI scientists are advancing the field of landscape epidemiology through an innovative blend of state-of-the-art computational techniques applied to long-term, national-scale datasets on key crop pests and diseases. For example, the powerful mapping and geostatistical tools of ArcGIS were applied to the data to provide an unprecedented overview of the distribution of these pests and diseases across Scotland, and how they are changing over time. This led to the discovery of striking geographical differences in long-term disease outcomes across Scotland. The knowledge gained is informing plant health policy and regulatory agencies and alerting growers of their geographical risk.

Machine learning techniques were then applied to the data to investigate the causes of these epidemic patterns and investigate why some geographic areas are persistent 'hot spots' for outbreaks. This provided the first analyses to rank the importance of various crop, management, and environmental factors as landscape-scale drivers of key crop pest and diseases affecting Scottish agriculture. The epidemiological insights gained have led to new hypotheses for testing in future research and are informing the development of new integrated pest management strategies.



Biocontrol as an Integrated Pest Management (IPM) Tool

Providing evidence for the use of pesticide alternatives

Contact: Ashleigh Holmes – Ashleigh.Holmes@hutton.ac.uk

Biocontrol is the term given to the biological control of a weed, pest or disease through the introduction of another organism or natural by-product. There are multiple mechanisms of control through the introduction of a biocontrol agent, including predation or parasitism; stimulation of the plant's ability to defend against pests and disease ('induced resistance'); or interrupting the ability of the pest or disease to recognise/live on its host (chemical mediators, e.g. pheromones).

Biocontrol is considered an environmentally friendly, and sustainable, alternative to chemical pesticides and can include the development and use of biopesticides. Understanding the practicalities, efficacy and potential ecological impacts from the use of biocontrol treatments is a key goal from the Revised National Action Plan for the Sustainable Use of Pesticides (Plant Protection Products).

SEFARI research will provide evidence for the implementation of pesticide alternatives and liaises closely with industry across all arable and horticultural crops impacted by the reduction in availability of approved pesticides.

Chemical control options have never been available for Potato blackleg, a bacterial plant disease caused by Pectobacterium or Dickeya species which can cause up to £50 million in annual losses to Scotland's seed potato industry from downgrades and rejections. We are undertaking collaborative research into the application of bacteriophage, natural viruses specific to bacteria, or bacteriocins, natural non-chemical antibiotics, as biocontrol methods to control blackleg in the field and/or yield loss from tuber rots in storage.

'Induced resistance' of plants can be stimulated by the application of elicitors, such as laminarin (from brown seaweed) or potassium phosphonate, and other micro-organisms, such as Bacillus spp. as biopesticides. Our research compares the outcomes of including these approaches in an integrated pest management (IPM) plan for disease control in spring barley and potatoes.

Plant Probiotics: Manipulating Natural Biota to Boost Disease Resistance

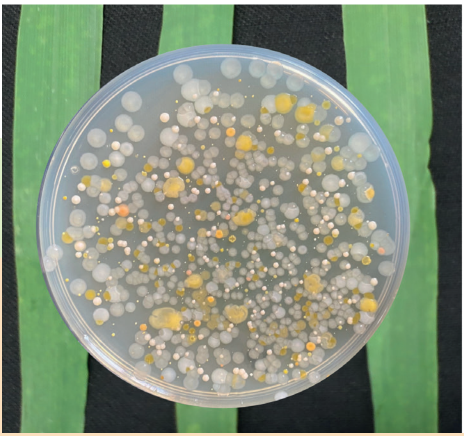
Customising a healthy microbiome

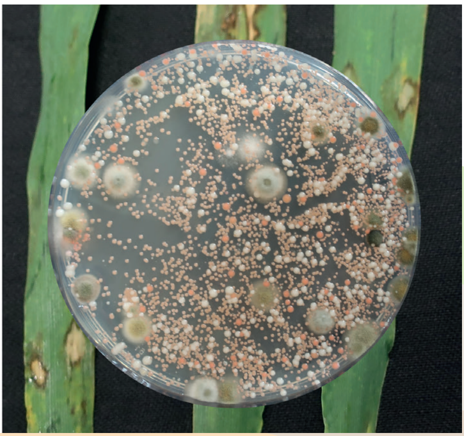
Contact: Lorena I. Rangel - Lorena.Rangel@hutton.ac.uk

Agricultural yield losses caused by disease are a major challenge to food production. Crop yields are reduced because of disease caused by both root (rhizosphere) and foliar (phyllosphere) pathogens. Plant tissues simultaneously house mutualistic microorganisms on plant surfaces (epiphytes) and within plant tissues (endophytes). This environment harbours a diversity of microorganisms including, but not limited to, bacteria and fungi. This environment is rich with microbes that have evolved to exist on the plant and withstand biotic (e.g. pathogen) stresses. Little is known about the multipartite interactions occurring between pathogens, host plants and what are considered microbial commensals (commonly termed microbiome), although these interactions surely affect disease outcome.

Currently, disease control involves breeding for disease resistance, the application of agrochemicals, and various integrated pest management (IPM) approaches. There are challenges associated with each of these strategies such as the breakdown of plant resistance genes, evolution of pathogen resistance, human health and environmental risks from chemicals, as well as situations where classic IPM strategies are not feasible or effective. One way to supplement or boost disease resistance is through bioaugmentation of the natural plant microbiota to offer defined benefits to the plant host.

These ‘plant probiotics’ are often referred to as biostimulants by industry. These biologicals can be retrieved from the crop of intended use. The plant microbiome can be manipulated through integrated cropping and soil amendments that can lead to pathogen suppressive soils. SEFARI research is employing next generation sequencing techniques to identify changes in endemic diseases and risk of new diseases in a changing climate. Using knowledge from DNA sequencing data we aim to determine what constitutes a ‘healthy’ or ‘diseased’ microbiome, with the ambition of customising the introduction of biologicals that promote healthy microbiomes. Supplementing current agricultural inputs with alternatives to conventional pesticides, we will work towards novel IPM strategies for crop resilience.





Effect of Management Practices on Soil Fungal Communities

Tillage and cover crops affect community composition

Contact: Maciej Kaczmarek - maciej.kaczmarek@sruc.ac.uk

Fungi are fundamental pillars of the soil microbiome in agroecosystems, profoundly influencing various soil processes, which in turn can translate into crop and soil health outcomes. Conventional agriculture has resulted in reduced soil fungal biodiversity and continues to threaten key fungal species crucial to agroecosystem function.

Regenerative farming practices, such as reduced tillage and cover cropping, are increasingly being adopted to address the detrimental impacts of conventional agriculture. However, little is known about the effects of these practices on soil fungal communities.

SEFARI research utilised high-throughput DNA metabarcoding and culture-based methods to characterise and compare the effects of minimum tillage and conventional ploughing along with two commonly used cover crops (hairy vetch and mustard plant) on soil fungal communities in the field.

It was shown that various aspects of fungal community composition, such as species richness, diversity, relative abundance and putative ecological function varied between tillage methods, indicating a potential influence of tillage on specific types (taxa) of fungi. Cover crop choice in the plough system resulted in differences in diversity and composition. The study also identified key indicator species and specific taxa of potential interest in agricultural management.

The Development and Use of an IPM Planning Tool

Optimising the use of disease management approaches

Contact: Neil Havis – Neil.Havis@sruc.ac.uk

Integrated Pest Management (IPM) is a holistic, systems-based approach to reduce the risk of pests, weeds and diseases in crops and minimise reliance on pesticides and other artificial inputs. Various SEFARI projects are working on the delivery of different interventions, such as the use of more resilient crop varieties, catch crops or biopesticides.

However, getting the right approach at a farm level remains complex. A recent key innovation was a user-derived metric to 'measure the unmeasurable' and allow growers to score what they are doing. This IPM planning tool was developed with stakeholder groups such as the Voluntary Initiative and is hosted on the Scottish Plant Health Centre's website. In 2024 almost 3000 Scottish users completed plans, and it is integral to crop assurance schemes such as Scottish Quality Crops.

In 2025 the plan will be central to Scottish Agricultural Policy and an annual option within the Whole Farm Plans being taken up as part of the changes to agricultural payments and support (as Tier 2 measures). The plans (designed for use by arable farmers) were reviewed and considered by the Agricultural Reform and Implementation Oversight Board, of the Scottish Government. To support policy developments two new plans have been developed, relevant for use by grassland farms and for horticulture.

Related research has looked at which measures farmers take up and where they go to for information on IPM. This highlighted that the farmers who score highest for IPM are those who implement preventative and planning measures on their farm. It has also highlighted that the more familiar they are with IPM the better they score. Agronomists are a key source of information and exert a major influence on IPM practices. Key messages are that the aim is to baseline farms and take advantage of the tailored suggestions that are generated when farmers complete the plans. It is a chance for agronomists and growers to discuss options.

Tackling an Issue Collaboratively: PCN Action Scotland

Celebrating the success of PCN resistant varieties

Contact: James Price – James.Price@hutton.ac.uk

youtu.be/3HW8fz28c3g

Potato cyst nematodes (PCN) are currently the largest pathogenic threat the Scottish potato industry is facing. These parasitic roundworms cause devastating yield losses and statutory regulations prohibit growing of seed potatoes on land where PCN has been detected. Despite regulatory controls, PCN has continued to spread on seed land and threatens the future of the crop.

In 2020, PCN Action Scotland was established to help manage the current epidemic, preserve the land base for future generations and increase the sector's capability to implement change. This is the single largest plant health project ever funded by Scottish Government through Scotland's Plant Health Centre. The group works collaboratively with representatives across the potato sector including growers, agronomists, researchers and government.

The project greatly benefits from work dedicated to knowledge exchange and interactions with policy teams, enabling changes to be enacted across the sector. The group has raised awareness and understanding of PCN across the UK, assisted by large open field trials with demonstrations of host resistance, tolerance, groundkeeper management and cover crops.

High impact press stories spanning all BBC platforms reached approximately 5 million viewers, alerting the public to this issue. The impact of collaborative work on this scale is visible in market changes. PCN-resistant varieties were shown in field trials to be marketable, capable of significantly reducing PCN populations and suitable for Scottish climatic conditions. Pre-sales for seed of these varieties for the 2025 ware crop are in excess of 1600 tonnes, unheard of for new varieties. In 2022 2% of the ware varieties grown in Scotland were resistant to the PCN species Globodera pallida. An increase to 15% in 2025 can clearly be associated with PCN Action Scotland work.

Growing PCN-resistant seed to meet this demand will help prevent current PCN-free land from becoming infested and, where the resistant seed is grown, reduce PCN populations present in infested land.

Ensuring Future Resilience to Pests and Diseases - a Multi-disciplinary Approach

Monitoring and diversification may be key

Contact: Luz Maria Lozada - maria.lozada@hutton.ac.uk

The impact of pests and diseases on Scottish agriculture is exacerbated by environmental stresses such as climate change and soil degradation. To understand these interactions, SEFARI researchers conducted scenario planning with agricultural stakeholders: the work aimed to explore how resilient Scottish agriculture will be to future pest and disease threats and recommend actions for farmers and agronomists, regulators, policy and research that will strengthen the sector against these threats.

Four plausible future scenarios on a 10-year time frame were co-developed and assessed for their robustness to pests and diseases predicted to become established in Scotland. The scenarios and recommended actions favouring desirable outcomes and mitigating negative outcomes were disseminated to audiences in farming, policy, and research.

Recommendations included increasing support for farmers to monitor for pests and diseases and to diversify cropping systems, improving controls and inspections on imported plants (a major route of pest and pathogen ingress), and research into cropping practices that buffer against crop losses and tools that support targeted control.

SEFARI scientists are taking action by collaborating with growers and other agriculture stakeholders to develop methods for combatting new insect pest problems resulting from a changing climate.

Future scenarios co-developed with agriculture stakeholders:

'better not best' and 'worse not worst' case scenarios

'Scotland's own vision'

'Agriculture elsewhere'

'Scotland feeds the world'

'Crisis is Scotland's opportunity'

READ THE FULL REPORT

Charles Bestwick
Director
SEFARI Gateway

Kenneth Loades
Soils and Crops
Knowledge Broker

Contact us

www.sefari.scot

@SEFARIscot
#LeadingIdeas

info@sefari.scot