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Leading ideas on crops
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Leading ideas on crops

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.

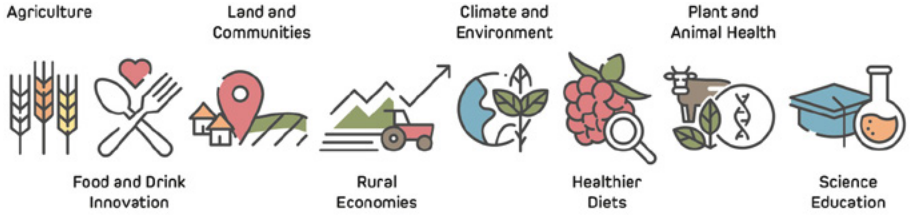
The six institutes are:

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

Through collaborative interdisciplinary research, SEFARI are responsible, with Higher Education Institute partners, for delivering the Scottish Government (Rural and Environment Science and Analytical Services, RESAS) funded Strategic Research Portfolio on environment, agriculture, land, food, and rural communities (2016-2021). The Portfolio includes the Strategic Research Programme (SRP), Centres of Expertise, Innovation Partnerships and Underpinning Capacity funding of national resources within SEFARI.

The SEFARI Gateway is the knowledge exchange and impact hub for SEFARI. The Gateway works to enhance stakeholder access to the expertise of the Portfolio; to improve the flow of research and knowledge to and from the Portfolio across Scotland's policy, industry-sector and public audiences and to increase the impacts from those activities. Gateway also seeks to ensure that Portfolio research is actively informed by stakeholders and knowledge networks across Scotland, UK and internationally.

SEFARI focuses its work under eight 'Leading Ideas'



This leaflet highlights key research outputs from Scottish Government funded strategic research including: optimisation of crops for environmental and nutritional benefits, integrated pest management, and the circular economy. Each article relates to 'One Health' with benefits to both the agricultural system and in public health outcomes. Crops play an important role in many systems with outputs delivering to Scotland's Centres of Expertise for Climate Change (ClimateXChange), Waters (CREW), Plant Health (Plant Health Centre) and Animal Disease Outbreaks (EPIC)

Charles Bestwick
Director
SEFARI Gateway

Kenneth Loades
Soils and Crops
Sector Lead

Contact us

www.sefari.scot

@SEFARIscot
#LeadingIdeas

info@sefari.scot

A one health approach for Scotland's crop production

Main contact: nicola.holden@hutton.ac.uk

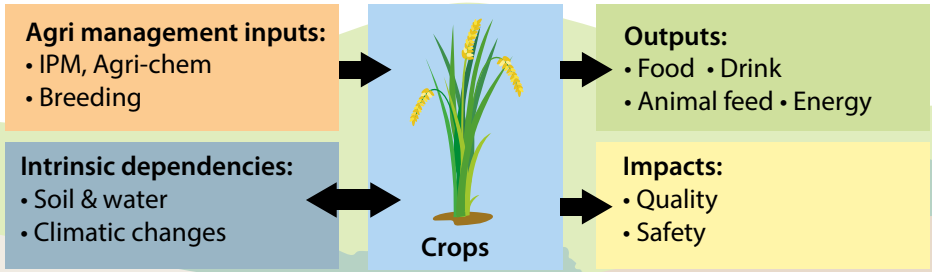
A 'One Health' approach combines multiple sectors and areas of research to improve public health outcomes. In crop production, plant health directly impacts human health through crop yield and quality, nutrition, and food safety. It also links directly to livestock health through improved animal feed and better animal inputs to cropping systems through use as fertiliser.

Crops are produced in Scotland for a range of purposes: food and nutrition; animal fodder; fruit juices and alcoholic drinks; bio gas for energy production. Where previously these were, to a large extent, historically separated they have been merged to create a One Health approach. Through this consolidation of previously separate areas of research, and engagement with Scotland's Centres of Expertise (EPIC, Plant Health Centre, CREW and ClimateXChange) understanding within multiple areas, potentially vulnerable to change, can be strengthened.

Through a One Health, systems approach, plant health is improved by reducing the burden of pests and disease, reducing wastage in the field and spoilage post-harvest. Achieving improved plant health is through optimal integrated pest management (IPM), utilising research platforms within SEFARI, such as the Centre for Sustainable Cropping, which allow the effects of novel approaches to agricultural management strategies be better understood. Strategies include breeding for pathogen resistance, understanding infection mechanisms (such as possible links between diseases, integrated pest management and Agronomy), and appropriate post-harvest management in reducing waste can help in achieving a circular economy. Optimising plant health improves product quality and associated nutritional benefits, waste reduction, and processing benefits.

Food safety is a key consideration in crop production, ensuring crops are free from human and plant pathogens and contaminants such as from animal waste, agri-chemical residues, or fungal toxins.

Inherent dependencies on soil health and water quality, and impacts from climatic changes are incorporated into crop production research, to determine their role in crop heath, quality, yield or safety.



Crop agronomy

Main contact: fiona.burnett@sruc.ac.uk

Market difficulties, coupled with the climatic extremes of an exceptionally wet autumn and a spring drought, highlights some of the challenges our crop agronomy research has been addressing. Our focus on producing crops sustainably and profitably, using tailored agronomic approaches, builds on long standing programmes of previous work. Key research focusses on reducing the reliance on artificial inputs, making crops more resilient to climatic extremes and helping the industry move towards meeting Scotland's carbon net zero targets including:

- Improved varieties with enhanced disease or pest resistance and greater tolerance to climatic extremes. Crucially theses are linked to sector priorities through industry funding and sharing of knowledge. Effective implementation is driven through our knowledge exchange programmes targeting key farming issues e.g. responses to potato cyst nematode and ramularia in barley
- Work on the efficient use of nutrients and integrated pest management approaches to minimise pesticide use, increase biodiversity and improve soil health. Integrating crop physiology, varietal resistance, new fungicides and novel alternatives has led to better advice and the development of planning tools facilitating tailored and targeted agronomy inputs
- Research on systems and rotations greatly benefits from using SEFARI research farms (at James Hutton Institute and SRUC) supported through Strategic Portfolio underpinning capacity funding. Key findings include increasing the use of legumes with the potential to reduce the carbon footprint of arable farms by 14%

Close collaboration with the Strategic Portfolio's Centres of Expertise for Plant Health, ClimateXChange and CREW has optimised best practice, knowledge exchange and maximised the input of stakeholders, enabling us to explore barriers to uptake, incorporate the preferences of end users and improve the flow of research to farmers.

Integrated pest management: a balancing act

Main contact: alison.lees@hutton.ac.uk

Growers and producers of Scotland's major crops, including potato, soft fruit, barley and oilseed rape, face the challenge of delivering a sustainable, high quality and profitable product. Pests and diseases make crop production untenable if not adequately controlled, and some pesticides are being lost due to legislation and reduced efficacy. Integrated Pest Management (IPM) balances the need to reduce food losses, to cause minimal disruption to agro-ecosystems and to adapt practices to cope with environmental change with the need to manage pests and diseases effectively. Research conducted by SEFARI scientists focuses on developing specific tools, integrating their deployment at the field and farm-scale and understanding barriers to their uptake in practice. For example:

- Tool: elicitors, which stimulate defence responses in plants, were shown to produce significant yield benefits on winter barley affected by powdery mildew and rhynchosporium, and significantly improved the control of potato late blight when used in combination with fungicides
- Tool: the flight activity of Spotted Winged Drosophila, a pest threat to soft fruit, can now be forecast using an algorithm developed using weather data. This tool is being further developed for use by the soft fruit industry
- Integration: best practice IPM options implemented over a 6-year rotation at the Centre for Sustainable Cropping were shown to be more specifically targeted and were not detrimental to crop health
- Uptake: farmer survey data revealed positive relationships between IPM adoption, farm area, and familiarity. An impartial source of information on pest control was shown to be influential on farmer familiarity with IPM

Practical IPM measures, resulting from fundamental and applied SEFARI research, in conjunction with precision agriculture innovations, will continue to have impact in maintaining or improving food- production during the transition to lower-input agricultural systems.

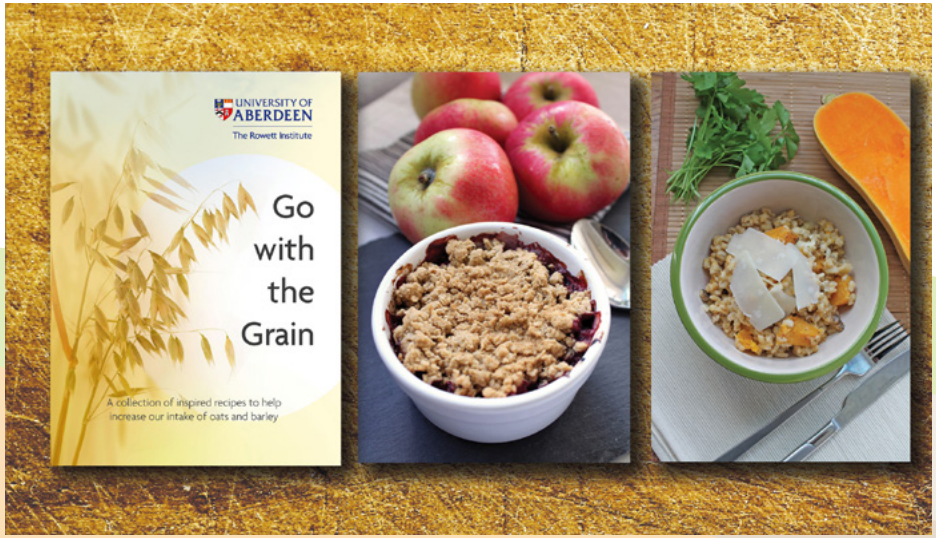
Barley benefits for human nutrition

Main contact: w.russell@abdn.ac.uk

Although a staple in other parts of the world, barley remains underutilised as a human food source in Scotland where only 2% of UK-grown barley is used directly for food. Consumption of wholegrains such as barley has been associated with a reduced risk of a number of health disorders such as cancer, heart disease and Type 2 diabetes. This may be due to high levels of fibre, particularly β-glucan for which there is a recognised health claim, and bioactive phytochemicals, some of which have been shown to reduce inflammation. Our research is focusing on identifying barley that is enriched with these healthy components with the most promising being studied in terms of processing, human metabolism and benefits for health.

- Several barley varieties have been identified that are higher in β-glucan and anti-inflammatory compounds compared to those currently commercially available
- Key for realising and maximising health benefits will be to maintain dietary nutrients and that other bioactive molecules are not lost during processing and so ensuring effective food formulation
- To encourage consumption of barley, a recipe book; 'Go With the Grain' has been developed and widely disseminated

As we look to developing healthier barley varieties for human consumption, processed in a way that will retain these benefits, a key consideration is the need to lower inputs, such as fertiliser and pesticide use, during production. The next steps are to identify or develop seeds, which have the desirable grain composition that could help meet environmental, nutritional, consumer and industry demands



Re-entwining hemp in the food system

Main contact: w.russell@abdn.ac.uk

Hemp has been a traditional part of Scotland's industry and is suited to both our climate and growing conditions. As well as potential financial benefits for farmers and producers, hemp brings environmental advantages due to its capacity for carbon sequestration, contribution to greater biodiversity, land recovery and remediation. Early research in the 1990s explored hemp fibre and since 2012, an active research programme has been investigating the potential of high-protein crops, such as hemp, that could be sustainably grown in Scotland. Hemp demonstrated an excellent nutritional profile to support dietary diversification and has a genuine potential to benefit human health. Findings supported further work on food formulation to meet industry and consumer demands. In 2019 the Scottish Hemp Group was founded, involving and supported by SEFARI, serving as an important driver for the development of hemp as a crop:

- Hemp has been shown to be a rich source of protein (36%), dietary fibre (26%), healthy fats (6%), micronutrient minerals (such as magnesium, calcium and zinc), as well as a variety of bioactive phytochemicals
- Interdisciplinary collaboration with an award-winning multi-arts organisation is expanding the reach of our work; encouraging sustainable high-value use, as well as facilitating the education and promotion of hemp with a wider audience
- The Scottish Hemp Group works with all sectors, from primary producers to consumers, promtoing hemp in Scotland for food, feed, energy, biomaterials and as a cash crop promotor of circular green economies and new markets

Hemp has shown significant potential to play a key role in the development of a low-carbon, environmentally responsible, industry. The benefits of hemp are contributing to the current program for early action to accelerate Scotland's journey towards net zero by 2045.

Resistance to pests and diseases

Main contact: ian.toth@hutton.ac.uk

Pests and diseases lead to crop losses of 40% worldwide and up to 25% in Europe even with use of the latest crop protection methods. However, as Europe looks to reduce chemical inputs, due to human and environmental concerns, we must now take a more holistic Integrated Pest Management (IPM) approach to reduce losses.

Traditionally, breeding for resistance has taken years to accomplish yet with modern methods there have been major advances in molecular breeding. Such approaches are central to work within the SRP for identifying resistance genes in potato and soft fruit across a range of pests and diseases. Underpinning such research is the Commonwealth Potato Collection (CPC), and historical and contemporary pest and pathogen collections, providing invaluable genetic material for our studies.

For potato, through the enrichment of resistance genes, the rapid identification, characterisation and mobilisation of new disease resistance varieties against potato cyst nematode, viruses and late blight has been possible due to the CPC. For raspberry we have also uncovered resistance mechanisms to pests and disease and aim to predict their durability in resistant cultivars. For example, we have identified a marker for resistance against Phytophthora root rot which has led to the development of Glen Mor, the first commercial cultivar with root rot resistance.

Within barley a major issue is the pathogen Ramularia *collo-cygni* which, as with many other pests and disease, has historically relied on fungicides for control. We are currently using genome-wide analyses to identify candidate genes for use in the development of disease resistance barley plants.

There is a critical need to tackle both existing and new pests and diseases such as the potato cyst nematode, which costs the UK an estimated £50 million annually, a figure likely to increase in the future, and diseases such as with Ramularia *collo-cygni* in barley which costs approximately £10 million annually. Such development through breeding of more resilient varieties all contributes to a holistic IPM approach.

Crop yield and quality

Main contact: mark.taylor@hutton.ac.uk

Research into crop yield, and quality, builds on genetic and genomic resources established through a long history of funding within the SRP. Strategic funding has supported barley and potato collections and genome sequencing projects for Scotland's key crops.

The malt whisky industry is economically important and is almost entirely based on the use of spring sown barley. Despite higher yields from winter sown crops, they do not have the necessary quality needed in whisky production. Current and historical research has enabled us to develop improved winter barleys that are already being utilised in commercial breeding programmes. A malting quality winter crop will bring practical advantages at harvest, improving sustainability and spreading the risk of failed crops within the industry.

In potato, a genetic approach has enabled the identification of a gene that has a key role in controlling both tuber initiation and tuber sprouting following post-harvest storage. These aspects are critical to the utility of the potato crop with findings allowing the development of new, improved, varieties and in reducing waste.

A key barrier to meeting the significant market expansion for UK produced blueberries is the large annual yield variation observed in the UK crop. SEFARI scientists discovered that yield is limited by CO_2 assimilation which varies based on seasonal light availability. To resolve this, reflective mulches were deployed resulting in yield uplifts of 50% via increased light availability irrespective of seasonal conditions. This strategy has been adopted by several Scottish growers and ongoing research aims to further improve yield management to support local food production and the rural economy as part of a green recovery.

Crops and climate change resilience

Main contact: mark.taylor@hutton.ac.uk

For long term food security and to maintain crop quality, understanding the genome sequences of Scotland's major crops is vital. New genomic/genetic approaches build on the Scottish Government SRP funding to accelerate breeding of new and improved varieties.

As part of the International Barley Sequencing Consortium, key genomic resources have been developed key genomic resources to address the challenges of sustainable and resilient production in a changing climate. Since barley has a wide natural ecological and geographical range and a long history of cultivation, we have assembled and sequenced over 1200 different types to identify important new sources of variation for traits that underpin sustainable intensification. In parallel, climate model data has been used to simulate spring barley yields under future conditions. This enables crop growth to be estimated and provides information on key traits needed in future varieties.

In other crops, lack of winter chilling is having a negative impact on soft fruit production, however recent SRP research has identified blackcurrant varieties with a reduced requirement for cool winter temperatures.

For most potato varieties tuber yield is highly susceptible to even moderately elevated temperatures. SRP research has identified sources of heat tolerance in the Commonwealth Potato Collection. Within a collaborative network spanning Europe and Africa, we are trialling potato types carrying traits for heat and drought tolerance. These studies aim to develop heat resilient potatoes that will prevent the yield loss due to warm conditions estimated at 2.4t/ha in the UK in 2019.

Research into the climate resilience of our crops must also take into account effects on pathogen populations driven by climate change, a priority area for the Plant Health Centre.

Crops and the circular economy – feeding the cycle

Main contact: derek.stewart@hutton.ac.uk

For life to be sustainable we need to reconsider all our activities and evolve from our current approach of take-make-dispose. A move towards a circular economy is required in which we maximise the use of our resources through innovation and redesigned processes to recycle, reuse, repair and remanufacture.

The Scottish Government funded SRP has delivered success in this area, adding value to agricultural waste. Projects have included: recovering protein from the oilseed rape press cake, a waste product, or conversion into a gluten alternative in baked products; exploiting soft fruit that do not meet supermarket standards into a sustainable source of food colourants; developing dermal abrasive products from waste cherry stones.

These early steps toward a Circular Bio Economy are supported by a recent report by Zero Waste Scotland, supported by SEFARI scientists, highlighting the Biorefining Potential for Scotland. Our work has identified over 27 million tonnes of materials suitable for biorefining. Following processing, the bioresources could be used in a variety of sectors including chemicals, bioplastics, food ingredients, adhesives, fuels and applications related to energy.

From a farming perspective the Circular Bio Economy can operate both on and between farms. Examples include the use of manure for green fertiliser and can add significant value to other biomass such as cereal straws for their conversion into bioplastics.

Our collaborative approach is working to optimise the potential for a Scottish Circular Bio Economy. Only through this interdisciplinary and innovative approach will we create a significant and diverse portfolio of efficiencies and business opportunities for the rural economy in the future.

Contact us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info@sefari.scot

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