



**Sustainable barley production for  
future health of people, community  
and environment.**

Dunkeld House Hotel 5<sup>th</sup> to 6<sup>th</sup>  
February 2020



## Introduction

Barley is Scotland's most important crop and is underpinned by a world leading Scottish research community with strong end-user demand. However, now we must address the challenges of producing more food with fewer inputs, and in an unpredictable climate. Our barley research strategy for crop improvement, land management and post-harvest processing must reflect these drivers to ensure future growth and resilience across the barley value chain.

The success of barley cropping is built on breeding for productivity and quality, typically with high input levels. To maintain genetic gains in a sustainable manner requires a holistic, innovative and collaborative approach within the barley research community, with an appreciation of end-user demands.

With funding from SEFARI and SSCR, we invited stakeholders from across the barley supply chain to a two-day meeting to, firstly, communicate the depth and breadth of the barley research conducted at the MRPs and, secondly, to discuss stakeholders' priorities and vision for the future.

## Two-day Event at Dunkeld House hotel 5<sup>th</sup> and 6<sup>th</sup> of February

### Attendees

In total 108 people attended the two-day meeting and Table 1 highlights the wide range of stakeholders representing the barley supply chain: from growers (farmers and crofting associations), agronomists (precision phenotyping), maltsters, brewers, distillers and bakers; as well as members organisations, such as the Scotch Whisky Association (SWA), Maltsters Association of Great Britain (MAGB), Scotch Whisky Research Institute (SWRI); and levy boards, such as Agriculture and Horticulture Development Board (AHDB). UK and Scottish organisations were also represented, including Linking Environment and Farming (LEAF) UK and Science and Advice for Scottish Agriculture (SASA). Members of charitable organisations were also present, including Soil Association, Scottish Crofting Federation, Reviving Food and Common Grains and Game and Wildlife Conservation Trust.

Table 1. List of participant affiliations

Precision agriculture	Agricultural Engineering Precision Innovation (Agri-EPI)
Regulatory Boards	Agriculture and Horticulture Development Board (AHDB)
	Linking Environment and Farming (LEAF) UK
	Science and Advice for Scottish Agriculture (SASA)
Distillers	Arbikie Distilling Ltd
	Diageo
	Scotch Whisky Association
	The Glenmorangie Company
	Waterford Distillery & Renegade Spirits
Food Industry	Agrii GB seeds
Maltsters	Boortmalt
	Crafty Maltsters
	Maltsters Association of Great Britain (MAGB)

Brewers	Carlsberg
	Law Brewing Company
Farmers	Durie Farm
	East of Scotland Farmers
Breeders	Elsoms Ackermann Barley Limited
	KWS Lochow GmbH
	Limagrain
	RAGT Seeds Ltd
	Syngenta
Trusts & Conservation	Game and Wildlife Conservation Trust
	Reviving Food and Common Grains
	Scottish Crofting Federation
Members Organisations	Scotch Whisky Association
	Scotch Whisky Research Institute
Universities	University of Dundee
	Scotland's Rural College (SRUC)
	Sabanci University, Istanbul
	University of Aberdeen
	Universitat de Lleida
	University College Dublin
	University of the Highlands and Islands
Institutes	The James Hutton Institute
	The Rowett Institute
	National Institute of Agricultural Botany (NIAB)

## Talks

The meeting was divided into four linked sessions, following the outline of the RESAS programme (2016-2021): Food & Drink; Genetics & Breeding; Sustainable Cropping; and Environment & Climate. Each session combined talks from stakeholders and academics, with a total of 24 speakers (13 male and 11 female). Below is a summary of each session.

### Wednesday 5<sup>th</sup> February

#### *Food & drink*

**Peter Nelson** from the Glenmorangie Company set the scene for this session and the whole meeting, by emphasising the need for **sustainable production and sources** of barley. For the whisky industry location is everything and they have a duty of care to the environment and the communities in which they operate. All agreed that the industry needs to move towards a more sustainable carbon-neutral supply of barley and this needs to be integrated into the supply chain. He emphasised that to produce a bottle of whisky results in 1 kg of CO<sub>2</sub> and the **aim is to achieve zero CO<sub>2</sub>**. He highlighted some of the impacts that our research has already had on the industry, including improved agronomy, processing and yield; significant improvement in winter varieties; and elimination of ethyl carbamate by developing a diagnostic marker. He summed up saying that we need to continue to strive scientifically to produce low-energy, resilient, high-quality strains of barley that are climate resilient and sustainable. He took this a stage further and suggested that we need 'end to

end collaboration and investment from seed production to distillery. Joined up thinking, joined up support, joined up funding. Please don't rely on the end-user, we need support to develop solutions to benefit the whole chain'. This sentiment was echoed throughout the meeting that we need joined up science and investment. His final statement was that there is **'A sense of urgency – we need to value both fundamental and applied research'**.

The next three talks described ongoing collaborative research into food barleys. The first was from **Ignacio Romagosa** from University of Lleida in Spain describing breeding for barley as a healthy grain. In Spain barley is the largest agricultural crop and almost 90% is used for animal feed and very little used for human consumption. But he highlighted the recent international funding initiatives to champion barley as a source of nutrients being particularly high in beta glucan and dietary fibre, citing various health claims to support this investment. He described the use of diverse barley accessions from across the world that have high beta glucans and purple grains high in anthocyanins, and the importance of developing new lines using classical breeding programmes. He emphasised that we can develop these new varieties, but they must be attractive and good to eat before they can be adopted by the consumer.

Ignacio's talk set the scene for **Wendy Russell** whose research is conducted at the Rowett Institute (RD 3.1.1) and has worked as part of RESAS funding on the benefits of cereals on gut and metabolic health. She described a similar approach to Ignacio's, looking at diverse barley accessions which are part of the heritage collection assembled by researchers at the James Hutton Institute. Her research includes work specifically looking at phytochemicals and crude proteins and she has carried out human studies to assess the health benefits and the availability in the gut and colon.

**Kay Trafford** from NIAB, took us on a tour of starch granules in the grain and described her work on modifying the different types, reducing the small starch granules, to improve malting and increase yield. She went on to discuss whether we could enrich nutrients in the grain by increasing embryo size. To do this, she identified mutants that have larger embryos and were shown to be nutrient rich. She is now working with Kelly Houston, Luke Ramsay and Joanne Russell from the James Hutton Institute to identify the genes involved and look for natural variation in a worldwide collection of barley accessions.

Taking this work a stage further, **Kelly Houston** from the James Hutton Institute (RD 3.1.1) described her work on identifying the genes involved in beta glucan production using state-of-the-art genetics and genomics approaches. Kelly introduced the technique of gene editing to validate her candidate genes. She described those plants in which she had knocked-out the gene and ones in which the gene was still present, the differences were striking. She further tested the beta glucan content, highlighting the absence in the knockout plants. Kelly concluded that this is an important tool that we can use to identify genes and, once identified, we can screen our assembled barley collections to identify novel variation that can be used by breeders to develop high beta glucan varieties.

The last talk of the first session was from **Barry Harrison** of the Scotch Whisky Research Institute on whether we can detect flavour differences in new spirit from different varieties of barley. He used 8 barley lines from the James Hutton collection, including old and elite cultivars, which were field-grown under the same conditions in 2018 and micro-malted at SWRI. Looking at the flavour profiles, he was able to show that older accessions, Scots Bere, Chevalier and Golden Promise, produced different flavour profiles from elite cultivars, such as Concerto, Laureate and RGT Planet. He also examined the aroma profiles and found differences, but these were subtle, with only sweet aromas being different between varieties.

## *Genetics & breeding*

Professor **Robbie Waugh** from the James Hutton institute (RD 2.1.1 & 2.1.2) and University of Dundee gave an overview of barley genetics, outlining the germplasm and technological advances made by the MRP institutes. He highlighted success stories, such as IMPROMALT, which was a collaboration with the breeding community and has resulted in the development of winter varieties with improved malting quality. He described work relating to the evolution and domestication of barley which has allowed the identification of important genes in adaptation. Robbie's last slide identified all of the important industry and academic partners that the barley group at JHI have been working with and hoped that these would continue and flourish as part of the IBH.

Following on from this, **Chris Burt** of RAGT seeds, a French breeding company with locations across Europe, emphasised the importance to the plant breeding community of collaborative research with academics and Institutions. He also highlighted some of the successful partnerships with JHI, including the development of state-of-the-art genetic marker platforms and novel pre-breeding material. He ended his talk with three areas which he saw as important for future collaborations and these included: continuing to improve winter varieties for malting and identifying the genes involved; understanding the biochemistry of malting; and similar large collaborative projects to examine new ideas, such as genomic selection for barley, similar to that currently underway in wheat. Finally, he emphasised that these types of partnerships between industry (breeding, distilling or food) and academics, are important as often institutions and Universities can adopt riskier approaches and strategies.

The previous talks had focused on grain, but there is more to barley than just seeds. Professor **Claire Halpin** from the University of Dundee described her ongoing work examining straw, specifically for biofuels. Claire gave an overview of biofuels and described her work on the project called MaxBio, which looks at the role of cell walls and specifically lignin. She highlighted the potential long term need for biofuels for some industries. Examining the considerable natural variation in barley cultivars, she identified potential genes that control lignin and increase digestibility of the straw for sugar release, providing the means to 'tailor' varieties for not only grain, but also straw for future uses.

From straw we moved to data-driven talks by **Micha Bayer**, a bioinformatician, and **Craig Simpson**, a molecular biologist, both at JHI (RD 2.1.1 & 2.1.2). Micha described the data explosion that has happened in the last few years and how we have been able to exploit these new data resources to improve our understanding of barley. He outlined how, since the first draft genome of barley was published in 2012, we have been continually improving the data and its analysis, and we now have a greater understanding of gene function and the organisation of genes in barley. Craig then described how he has used this information, not only to describe the different genes, but also to provide a reference for which genes are expressed. This becomes particularly relevant and allows us not only to determine when they are switched on to perform a particular function and under what specific conditions. Craig gave an example using this new database to identify over 100 genes that are differentially controlled during cold-stress. This new database is available now for the International barley community to use (**BaRTv1.0: Reference barley transcriptome**).

**Chiara Campoli** from the University of Dundee gave an example of where she has used the data generated by bioinformatics at JHI to identify genes involved in skinning, which is damage to the protective husk caused by mechanical abrasion during harvest or by weather conditions. This is a particular problem for malting and results in poor processing and conversion. Rather than examine natural variation, Chiara used a mutant population which allowed her to quickly identify the genes involved. A waxless mutant was compared to its waxy sister line, that is wild-type (i.e. non-mutant) by examining the sequence variation and identifying the differences. From this, she was able to identify a gene that is involved in husk

adhesion and is beginning to develop other lines to test this under field conditions. This type of mutant screen is now being used to identify other important genes in barley.

The last talk of this session was given by a recently graduated PhD student, **Senga Robertson** from the University of Dundee. She described her work to understand what goes on below-ground in the soil, what is termed soil microbiota. She outlined the importance of the soil microbiota in plant nutrient acquisition, compound excretion, gas exchange, water uptake, as well as having the potential to increase plant growth. To identify what types of bacteria are present in the rhizosphere and whether they possess the necessary functionality to improve plant growth, she set up pot experiments in different soils to isolate the microbiota and sequenced specific genes. Using this approach, she identified over 200 different isolates, of which 50 were analysed for functionality and found that many of the culturable isolates from the barley rhizosphere had multiple beneficial functions which would make them valuable as biological inocula. She concluded that this was a new area which needs further exploration with potential application in agriculture and sustainability.

#### Thursday 6<sup>th</sup> February

##### *Sustainable cropping*

**Ali Karley** from JHI (RD 2.3.8 & 2.1.8) set the scene for this session, but also for the breakout sessions, by outlining the three key challenges to agriculture: climate change, biodiversity and sustainable production. These are particularly relevant to Scotland, with over 80% of land under agriculture, including arable land, which is dominated by cereals, mainly spring barley. Ali posed the question 'How can we make cereal production sustainable and resilient with a smaller environmental footprint while conserving agrobiodiversity?' To address this, she suggests re-diversifying crop systems and introduced the term 'plant teams', which is defined as growing two crops in close proximity. She described the approach of intercropping cereals (wheat, barley & oats) with legumes (faba bean peas & lentils) and has carried out small- and large-scale field trials. Her results show, when grown in teams, yields of each component are similar to the crop under monoculture. This approach has been rolled out as 'participatory on-farm' approach in collaboration with the Soil association.

From the crops above-ground our next speaker, **Tracy Valentine** from JHI (RD1.1.1; 2.3.4, 2.3.8), described her work on soil. She first outlined some of the drivers, which include reduced tillage, complex rotations and the push to increase the level of C or N input from organic sources (e.g. using legumes, compost), all of which alter the soil composition, which is the focus of her research. She looked at the effects of tillage, comparing deep, minimum and conventional tillage on yield of barley, identifying variation across genotypes, but generally lower yielding with less tillage. To examine the plants response in more detail and specifically root traits, she used a range of state-of-the-art techniques, including transparent soil, which allowed her to image the roots in real-time. From her research, she concluded that the physical properties of soil change depending on the management, but with the development of new technologies we can measure these changes and with the genomics tools and germplasm collections available at JHI we can identify candidate genes that influences how plants impact on the soil and control these changes.

**Robin Walker** from SRUC (RD 2.3.8) described a long-term field experiment looking at the effects of different management systems on barley production and grain quality. Robin described 3 long-term field experiments, all based on legume rotation with cereals dating from 1922 to a more recent organic set-up in 1991. He discussed the merits of each of the systems, and the yields as well as grain quality. He concluded by stressing the need for maintaining funding for these valuable long-term experiments which allow researchers to test different cropping systems under real conditions over multiple years.

Following on from this, **Cathy Hawes**, from JHI (RD 2.3.8; 2.3.9), described the design and assessment of an integrated cropping system, known as the Centre for Sustainable Cropping. This platform has been running for over 10 years and compares conventional management with an integrated approach. The rotational and management systems provide the means to monitor the effects on soil, crop health and biodiversity, as well as seasonal changes. In general, yields were lower under the integrated system compared to conventional, however there was variation between cultivars and, in particular for barley, KWS Sassy out-yielded under integrated in 2018. Examining environmental indicators, she observed no difference in the number of grass weeds, but significant increases in beneficial broad leaf weeds in the integrated system. Similarly, she observed significantly more pollinators in the integrated system compared to conventional. Pulling all of the information together, Cathy described the use of a modelling approach called DEXi, which takes all of the generated information and provides a decision-making platform, which showed that the integrated management system had benefits on the environment, while the conventional system had economic benefits, the trick will be to define systems which have benefits in both. In the future, the use of modelling systems and improved monitoring will continue, and the platform will provide support for new projects.

The last talk of this session was by **Professor Ismail Cakmak** from Sabanci University in Turkey. He outlined the problems associated with micronutrient deficiencies and the role of crop agronomy, describing the deficiencies in micronutrients as the 'hidden hunger' resulting in millions of deaths every year. He talked about this in the context of soils and the micronutrients available for uptake. He produced figures showing that for most micronutrients the amounts in the grain are much lower than needed to maintain a healthy population. He described examples of where increased fertilisation increased micronutrients, project such as Harvest Plus and Harvest Zinc. He also gave examples of successful biofortification and concluded that we should 'Focus on better food, not only more food.'

### *Environment & climate*

The first talk of the last session was by **Caroline Drummond** who is the Chief Executive of Linking Environment and Farming (LEAF). She talked about LEAF perspective on cereal farming and the innovations for future sustainability. She described the global challenges we face in a changing world and talked about the lack of diversity in our diets, how 75% of our food is from 12 crop plants. The aim of LEAF is to deliver more sustainable food and farming. They work with farmers, the food industry, scientists and consumers, to inspire and enable sustainable farming that is prosperous, enriches the environment and engages local communities. The approach is based on an integrated farm management system, to lower emissions, increase productivity and enhance resilience. Throughout her talk she described examples of increased plant health through integrated pest management, improved biodiversity and pollinators and novel crops. Caroline closed her talk by saying that to deliver sustainable farming fit for the future requires new thinking built on traditional skills & expertise.

**David Michie** from the Soil Association Scotland talked about the organisation's agroecology research and policy. He talked about the changing and unpredictable climate, the loss of biodiversity and the increase in obesity in Scotland, and the role that an agroecological approach can provide to mitigate. He suggested that agroecological approaches would be long term and transformative taking into consideration wildlife, human nutrition and pollution of water, air and soil. David discussed the recently published document 'Ten years of Agroecology' (TYFA) which is a model-based study published in 2018. He described 6 main ideas: **Fertility** - managed at European level and would include no protein imports, include legumes in rotations and a more integrative approach to livestock and cropping; **Cropping** - phasing out pesticides; **Grazing** - permanent grasslands and agroecological structure; **Livestock** - extensification i.e. growing less feed for animals

reducing pigs and poultry; **Consumption** - healthy and sustainable diets based on nutritional guidelines; **Land use priorities** - human food production then feed. He talked briefly about each of these in turn and concluded his talk with perspectives for Scotland. These, he suggests, are that the productive lowlands be used for food production rather than animal feed; increase legume use; more crop rotations; use of livestock manures for increased fertility; and healthier diets that are sustainable and plant-based, this approach would have clear impacts on barley production in Scotland and would be a challenge for producers.

**Robin Pakeman**, from JHI (RD 1.3.1) continued on the theme of ecology and described his research on community assemblies in barley with specific emphasis on weed communities. He described what is meant by communities and increasing assemblies leads to more diversity within the system and importantly functional diversity. His research wanted to test that if we increase the barley diversity, we would reduce the space for weeds. To test this, he used 6 barley accessions with different growth habits, tall, short and prostrate, in all combinations of mixtures, in a replicated field trial and measured phenotypic diversity and weed communities. He observed that the more phenotypic and increased genotypes both reduced the space for weeds to establish, and this was a function of increased leaf area. Robin concluded that increasing within-crop diversity has a measurable impact on the weed community, but that no specific mixtures of genotypes or phenotypes had a consistent effect on community assembly or weed responses.

**Katherine Preedy**, from BioSS, described her work developing a modelling approach to examine natural pest control under abiotic stresses, increasingly becoming part of integrated pest management (IPM) systems. Very little is known about natural pest controls but they may become an important alternative to pesticides. The data used for the model was based looking at pest (bird cherry oat aphid – a major cereal pest) and natural enemies (parasitoids). The model developed determined that the rate of attack was key, and indicated that when plants were stressed, this influenced population dynamics and could potentially destabilise IPM system.

The last talk of the meeting was given by **Tim George** from JHI (RD 1.3.1), who described the work he has been doing on ancient barley landraces. He first described the value of using these old locally adapted cultivars, which in barley have been adapted to a wide range of environments during the spread from the Fertile Crescent in the last 10,000 years. He talked specifically about a group of landraces from the Highlands and Islands of Scotland, known as Bere barleys, which are thought to be the oldest landraces outside of the Fertile Crescent. He described that at JHI a collection of these has been assembled and genotyped with the 50K SNP chip, described previously by Robbie Waugh, also trialled and phenotyped on nutrient deficient soils on Orkney. Tim observed that the Bere barleys had a remarkable ability to survive on these manganese deficient soils compared to elite barley accessions, many of which did not set seed. Using this information, crosses between elite lines and Bere lines have been developed and 1000 of the segregating offspring were sown on Orkney in 2018 and their manganese efficiency measured, as well as leaf sampled for detailed nutrient analysis and genotyped. Plants were also harvested and grain weights measured. Those data are being used to identify candidate genes involved in manganese efficiency in barley which can be used in future breeding programmes to develop varieties that will yield on marginal land.

The meeting was summarised and closed by **Professor Tina Barsby**, the CEO of NIAB. Tina praised and congratulated all the speakers and highlighted the breadth and depth of barley research in Scotland. She was inspired and hoped that we continued this work under the banner of International Barley Hub (IBH) and she looked forward to further collaborations and the next meeting.

### **Poster session**

A poster and video session was held on Wednesday evening. We attempted to make this session more interactive and sent out instructions to presenters to explain their research in



few words and use visual aids. We had 24 posters which ranged from games with dice to explain recombination and meiosis to building gene models with Lego, many with prizes. We had several videos including work by the Game Conservancy on partridges, an agroecology view of the research across Scotland, an explanation of genetics and breeding and a description of an Ethiopian collection of barley landraces. Most of the presenters were PhD students or early career postdoctoral scientists. Many of us have viewed poster sessions at conferences and have often found them uninspiring, however we asked a range of our participants and everyone thought the poster session was the best they had attended, we actually had to drag people away to go for dinner.