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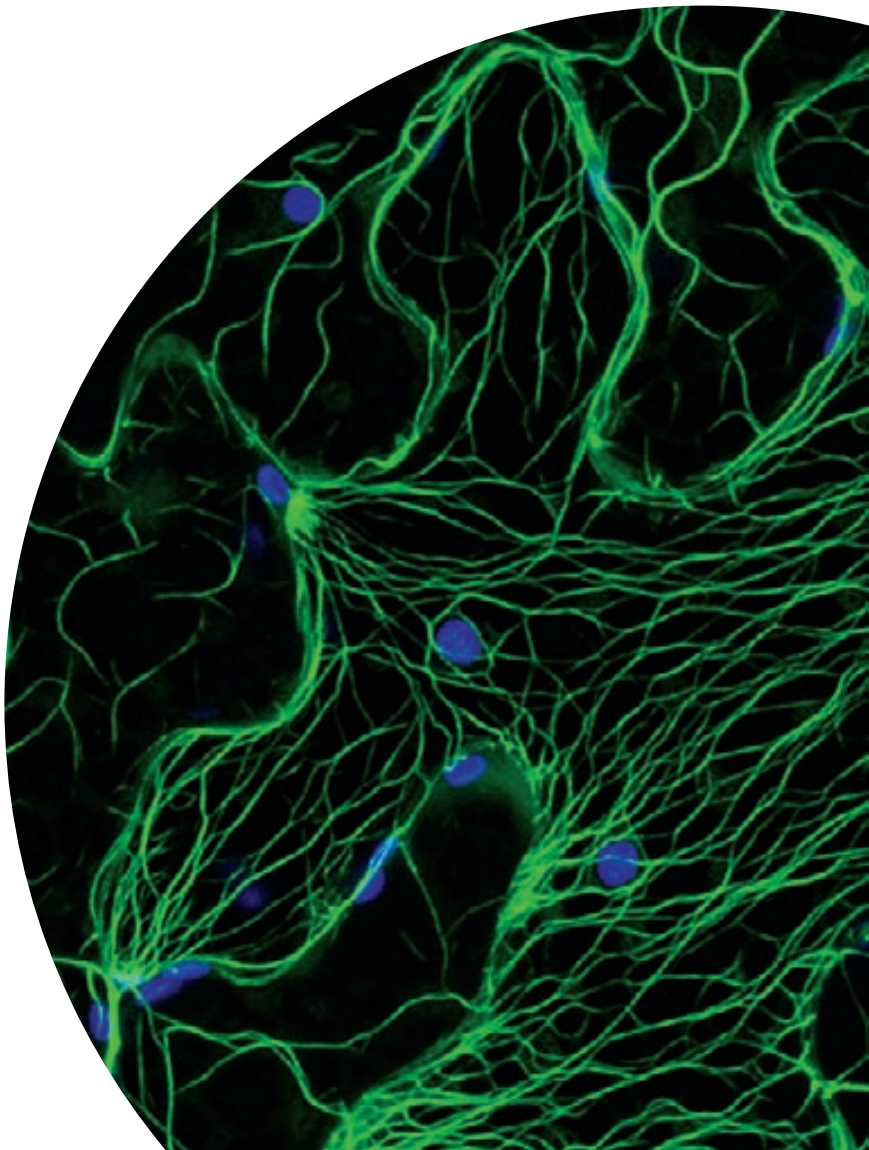
Annual Report 2009



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Cover Illustration: The Cell Biology & Imaging Group at SCRI has built up a library of transgenic plants that express stable, fluorescent markers in different cellular locations. This valuable resource lets us identify proteins of interest with organelle markers and work out likely functions based on their location. In the cover illustration, green fluorescent protein decorates actin filaments in a leaf epidermal cell while chloroplasts are shown in blue.

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Introduction

Peter J. Gregory

Although food prices in the shops and cereal prices on the world commodity markets have fallen from their highs in mid 2008, the wake up call to governments around the world has continued to foster interest in the issue of food security and associated concerns around water and energy supplies and use. During the year, we have been actively engaged in numerous workshops and discussions organised by the UK and Scottish governments, the UK research councils and internationally in meetings in Australia, Austria and India, and as part of the Copenhagen climate change talks on the subject of food security. The renewed importance of the topic is evident in the new strategy of the Biotechnology and Biological Sciences Research Council (BBSRC) in which it is one of three major themes along with bioenergy and healthy food. More locally, the Scottish Government, too, is engaged with interested parties in determining the research required to give substance to its Food and Drink Policy published in mid-2009 which aims to promote sustainable economic growth through work with Scotland's food and drink industry to address quality, health, wellbeing, environmental sustainability and the need for access and affordability. All of this debate highlights the importance of the research undertaken by us, and it has been very pleasing to see this recognised in both the various surveys of UK national capability in agricultural research and the reopening of BBSRC funding to us facilitated by the Scottish Government. These small individual steps will allow us to play a significant role in the emerging UK research programmes on issues related to food security.

Peter Gregory

In this context, the 'in principle' decision of our Governing Board and that of the Macaulay Land Use Research Institute (MLURI) to merge the two institutes from April 2011 is of considerable significance. The merger will bring together about 200 senior research scientists plus their support staff into a single institution capable of undertaking research across multiple disciplines and scales. The New Institute (the name has yet to be decided) will have a vision that encompasses 'excellence with delivery', a remit that has global reach, and a research focus on the environment/plant/land continuum and the uses that society makes of it. It will combine scientific and research excellence with delivery of knowledge, products and services to international, national and local customers. As with both SCRI and MLURI, the New Institute will be mission oriented and its research will feed directly into long term societal concerns relating to sustainable economic development, food/energy/water securities, environmental change, biodiversity, waste reduction and community development and wellbeing. Both institutions believe that by coming together at this time we can create a world leading institution that will be able to address these challenging issues in a way that, individually, would be impossible. As the economic recession starts to be felt in the public sector, we think that this timely initiative will place the New Institute in a position to attract scientists of the highest international quality and to broker access to the best minds and research in other organisations by providing global leadership in a broad range of land based disciplines.

SCRI Director Professor Peter Gregory interviewed by Radio Tay as plans for the 'New Institute' are announced.

Obviously substantial work remains to be done to make the New Institute a reality, and much of 2010 will be focused to this end. Already, though, agents have been appointed to recruit a Chairman and Chief Executive for the new company and we have held a joint meeting of the science programme leaders to familiarise ourselves with each other's research interests and to explore potential areas of synergy. Richard Aspinall (the Chief Executive of MLURI) and I have been working together on the science vision and on the business plan with the Scottish Government and consultants from Arthur D Little who assisted the Boards in making their decisions. We anticipate that the New Institute will play a leading role in the food security and multifunctional land use debates currently exercising governments and policy bodies.

The 2009 SCRI Director's summer soirée.

2009 marked the 20th birthday of Mylnefield Research Services Ltd (MRS Ltd) which was celebrated as part of the Director's summer soirée in July. MRS Ltd has continued to develop profitable business despite the recession, and we were very pleased to be able to appoint two new field geneticists who will undertake research in modern molecular genetics while receiving hands-on training in breeding of potatoes and barley. We hope that these 'trainees' will form the next generation of breeders, and so keep alive a skill that is in danger of disappearing from public sector research institutions. An allied activity has been the launch in October by our colleagues in the Division of Plant Sciences, University of Dundee of a Master of Research (MRes) course in Crops for the Future. Staff from the Institute are contributing to the course modules, but we hope that the project element of the course will also contribute to our research

activities and to our breeding programmes. MRS Ltd has successfully renegotiated the raspberry breeding contract with a consortium of growers, the Horticultural Development Company and the Scottish Government and we look forward to new varieties flowing from that work.

Our research continues to produce new knowledge and insights into the workings of plants, their pests and pathogens and interactions with the environment. In our Genetics programme a highlight of the year has been the public release of a draft genome sequence for potato together with international colleagues from around the world. In barley, a gene controlling fertility of the lateral florets in barley spikes has been identified, and with colleagues from the Division of Plant Sciences we have shown that the flowering regulator, FPA, functions in messenger RNA 3' end formation and that the nucleolus has a novel role in recognition and turnover of aberrant mRNAs. Software (Flapjack and Tablet) for visualising dense molecular genotype information and second generation sequence data respectively, has been developed by our informatics team and has been widely adopted by the international genetics community. Meanwhile staff in Plant Products and Food Quality have used a combined metabolomic, transcriptomic and sensory analytical approach to identify the key volatile components driving desirable potato aroma and texture, and the genes underpinning biosynthesis of the associated components. Collaborative research with partners in the UK and Europe has shown that berries such as strawberries and raspberries can inhibit pancreatic lipase. This enzyme controls fat digestion and associated calorie intake in humans and opens avenues for the dietary management of obesity and related degenerative diseases.

In Environment Plant Interactions, there has been a particular push to develop novel methods for studying root system development in natural substrates using x-ray tomography (with the University of Abertay, Dundee), rhizotron image capture and structured mesocosm techniques, combined with image tracking approaches. Results from these techniques are being used to inform mathematical models predicting how root architecture affects the acquisition of water and mineral elements from the soil, and how this might be manipulated for improved resource capture and ecosystem sustainability. As ever, our Plant Pathology programme has been very active and we were part of an international consortium that published the full genome sequence of *Phytophthora infestans*, the causal agent of the damaging late blight disease of potato. Availability of the genome sequence has had immediate effect in enabling a large number of pathogen effector molecules (pathogen encoded factors important in the disease process) such as transcription factors and proteins involved in secretory, signalling and ubiquitination pathways to be identified. These factors are being used to develop 'smart screens' to identify durable resistance in potato germplasm. In related work, we have used molecular markers to analyse isolates of *P. infestans* from >1000 late blight outbreaks in the UK and Europe. In the UK, data from >5000 isolates analysed in recent years show that populations of *P. infestans* are currently dominated by one genotype (designated 13_A2). This aggressive genotype is causing concern as it has overcome the resistance of some previously resistant commercial cultivars such as our own variety Lady Balfour. Work is ongoing to understand the biological and genetic properties that make isolates of genotype 13_A2 so successful.

January saw the launch of the BBSRC Sustainable Bioenergy Centre in which the Division of Plant Sciences of the University of Dundee, along with SCRI, plays a major part. The Dundee work will concentrate on altering lignin production in barley to make it easier to produce bioenergy from straw without reducing the quality of the grain crop. This research is an essential step in the development of second generation biofuels.

The high quality of our research has continued to be attested to by the external reviews undertaken by our Governing Board. In May it was the turn of BioSS to be reviewed. The team concluded that "BioSS is a first-rate organisation which is delivering international level research in fundamental science as well as statistics and bioinformatics methodology." This ringing endorsement of their work was much appreciated. The turn of Environment Plant Interactions came in November and again the programme received praise for its quality and

Dr Keith Dawson (left) receives a farewell gift from SCRI Chairman Peter Berry as he retires from the Governing Board.

the enthusiasm of the staff. Changes on the Governing Board this year were limited to the departure of Keith Dawson after eight years of substantial service during which he worked tirelessly for the promotion of the Institute, especially alongside the crop based skills of SAC (Scottish Agricultural College). Andrew Wilson joined the Board; his interests in communication and knowledge of politics and commerce in Scotland will be valuable to us.

We were very pleased at the award of the Jones-Bateman Cup of the Royal Horticultural Society to Julie Graham for her work on the genetics of soft fruit; this is vital underpinning research for our commercial breeding of new raspberry cultivars. The Director's Award for 2009 was made to Ian Pitkethly for his very substantial contributions to our publications, scientific posters and general communications. He will always go the extra distance to deliver high quality products against very tight deadlines, and this is much appreciated by a wide range of staff.

Dr Julie Graham of the Genetics programme is presented with the prestigious Jones-Bateman Cup by Giles Coode-Adams, President of the Royal Horticultural Society (RHS). Julie was honoured for her work on raspberry breeding.

I hope that you will enjoy reading about the rest of our activities in 2009 and learn something of the exciting research that we are engaged in to underpin food security.

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Environmental Change

Lesley Torrance

Our society faces serious threats posed by environmental change and increases in global population which will impact on food, energy and water security. The UK Climate Impacts Programme predicts that in the next 75 years Britain will become warmer, with drier summers and wetter winters and greater volatility resulting in unpredictable extreme rainfall and temperature events. Innovative solutions are required to adapt to, or mitigate, these effects and to promote environmentally and socially sustainable economic growth. Some of these effects are already apparent in Scotland; for example, this year we have experienced the wettest November in 50 years with other indicators such as earlier aphid migrations.

At SCRI we are conducting research to identify and counter risks from environmental change and develop solutions that will sustain the competitiveness of our agricultural industry while maintaining a vibrant and economically successful rural environment. The articles in this section illustrate the work we are doing on plant pathology, physiology and genetics to study the effects of temperature and water availability and increased pest and disease risks on Scottish crops.

Dormancy in blackcurrant and the potential effects of future climatic conditions

Rex M. Brennan, Hamlyn G. Jones*, Joanne R. Russell, Peter E. Hedley, Linzi Jorgensen, Chris A. Hackett & Sandra Gordon

One of the key environmental factors affecting cropping of woody fruit species is winter temperature, through its effect on the dormancy cycle. The degree of chilling received by the plants during the dormant period, to fulfill a chilling requirement that varies between species and cultivars, has profound effects on budbreak, flowering and ultimately fruit quality. In the UK, a study of historical data using a range of models for assessment of winter temperatures indicated a decline in levels of winter chilling over the past 50 years. Projected future increases in temperature suggest that in northern latitudes these will be proportionately greater in winter.

Blackcurrant is grown widely across northern temperate regions of Europe and also in New Zealand for commercial processing. UK production is based entirely on the SCRI 'Ben' series, from the earliest release 'Ben Lomond' in 1972 to the more recent 'Ben Starav' and 'Ben Klibreck' (2008). Blackcurrant has a relatively high chilling requirement, ranging from <1300 h below 7.2°C for some New Zealand cultivars to over 2000 h for some late-flowering Scottish types such as 'Ben Lomond'. Plantations of high-chill cultivars in southern locations, such as Kent and Herefordshire which have received insufficient chilling during recent UK winters, have suffered erratic budbreak and a subsequent reduction in harvested quality.

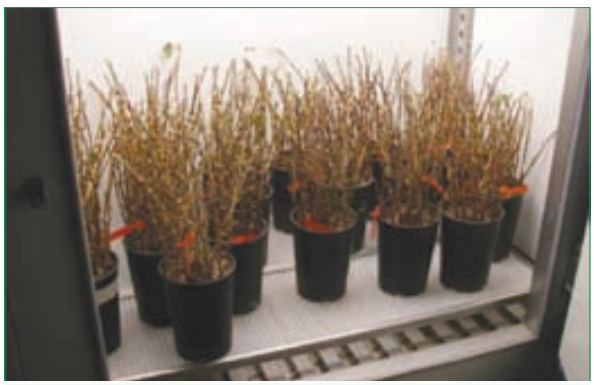

Figure 1 Phenotyping of blackcurrant cuttings for chilling requirement.

The response of blackcurrant genotypes to chilling temperatures was examined using controlled environment facilities at SCRI (Fig. 1). Hardwood cuttings of diverse genotypes were treated at chilling temperatures for periods between 5 and 21 weeks, after which the cuttings were moved to forcing environments so that budbreak and flowering could be assessed. The data were analysed using novel curve-fitting approaches, from which it was established that the various genotypes had very diverse chilling responses, with some cultivars, for example 'Ben Avon', responding only slowly to chilling temperatures while others, for example the French 'Andega', responding much more rapidly. Additionally, the calculation of an effectiveness coefficient for the different temperatures showed that the most effective chilling temperature varied between genotypes. Using this information, a high throughput method of phenotyping blackcurrant breeding progenies and advanced selections is under development, to assess their chilling requirement and enable the selection of environmentally resilient 'Ben' cultivars into the future. Collaborations with Plant and Food NZ are facilitating the use of low chill germplasm in the development of new progenies, and further investigation of climate effects on blackcurrant dormancy and development is planned across Scandinavia and northern Europe as part of the 'Climafruit' project in the EU Interreg North Sea programme.

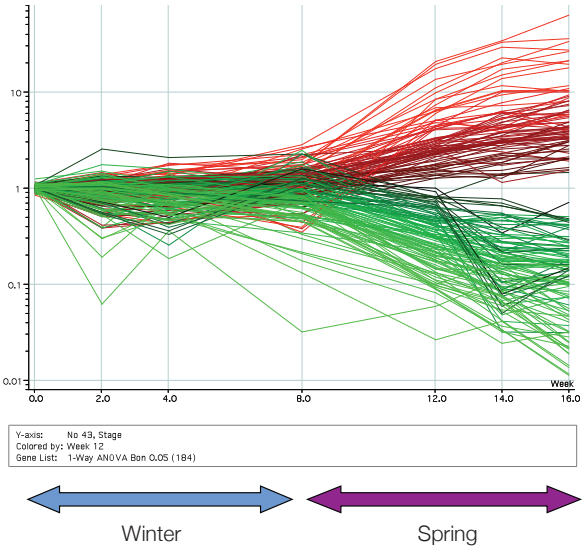

Figure 2 Microarray analysis of blackcurrant buds at dormancy break showing differential expression of genes.

* University of Dundee

At the molecular level, putative Quantitative Trait Loci (QTL) linked to budbreak and flowering traits have been identified on the genetic linkage map for blackcurrant, and further analysis is in progress using an extended reference population. Dormancy break and subsequent development is controlled through the coordinated action of large numbers of genes in woody plants. Differential gene expression during dormancy and budbreak in blackcurrant has been investigated (Fig. 2), and key genes associated with budbreak have been identified and mapped on the blackcurrant linkage map. Initial steps have been taken to develop associated markers that will then be deployed in the characterisation of the diverse *Ribes* germplasm in downstream breeding and mapping populations. The information on candidate genes will also have relevance to other woody species apart from blackcurrant.

The role of carotenoid cleavage products in heat responses of potato

Raymond Campbell, Laurence Ducreux, Wayne L. Morris, Peter E. Hedley, Glenn J. Bryan, Gavin Ramsay & Mark A. Taylor

The cultivated potato exists in a variety of forms originating from diverse environments such as coastal areas in Chile and dry Andean valleys at high altitude. The types finding favour across the world, including tropical and sub-tropical areas, are often those with high yield potential, bred in Europe and North America from a stock with its ultimate origins primarily in Chilean material and poorly adapted to high day and night temperatures. In fact most potato cultivars bred in temperate climates respond to high day and night temperatures with a reduced number of stolons (underground stems that form tubers) and tubers, and altered carbon partitioning to the tuber,

Figure 3 The *CCD4* silenced phenotype was characterised by early sprouting during tuber development or by the formation of chain tubers. These effects were observed in 20 out of 33 independent RNAi lines.

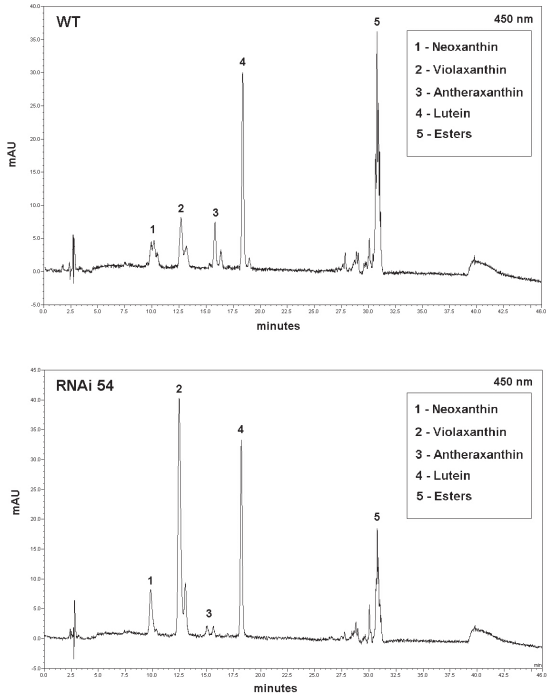

Figure 4 HPLC analysis of tuber carotenoid content in a *CCD4* silenced tuber compared with wild type (WT). Note the large increase in the violaxanthin peak in the *CCD4* silenced tuber.

resulting in a significant loss of tuber yield and quality. Climate changes due to global warming are expected to similarly affect the potato crop with warmer winters and summers predicted to increase abiotic stresses. Temperature fluctuation also causes economically significant damage to the potato crop. Growth under cool temperature interrupted by periods of high temperature leads to heat sprouting, chain tubers and secondary growth of tubers. This has serious effects on economic yield and tuber quality. These effects are due to a fluctuation in the level of stimulus that causes tuber formation to alternate with more stolon-like growth. This physiological problem can be a serious problem for some cultivars exported to or trialled in Mediterranean climates, and in the longer term may also affect tuber production in the UK.

The mechanism of heat sensing in plants is not fully understood, however it is known that the potato circadian clock can integrate environmental signals and thus modulate the level of tuberisation stimulus. It is also becoming apparent that signals derived from carotenoid pigments, by the action of carotenoid cleavage dioxygenases (CCDs), are potent regulators of plant growth and development. The classic example is abscisic acid, a well characterised carotenoid derived plant growth regulator. More recently it has been demonstrated that other members of the CCD family are involved in the biosynthesis of strigolactones, a newly discovered class of plant growth regulator that control plant branch structure. At SCRI we silenced the expression of the potato *CCD4* gene and this resulted in a dramatic phenotypic change. Tubers from silenced plants exhibited a heat sprouting phenotype even though they were not exposed to heat stress (Fig. 3). The phenotype was even apparent in tubers grown under *in vitro* conditions. Analysis of carotenoid content in the silenced tubers revealed that the carotenoid violaxanthin was the likely substrate for the CCD4 as its level was elevated several fold in the silenced lines (Fig. 4). There is no evidence for changes in abscisic acid or strigolactones in these plants. We are currently investigating the nature of the carotenoid derived signal that is implicated in temperature perception by these observations. Additionally we are investigating

whether elevated levels of *CCD4* expression can result in protection from heat stress and increased tuber yields under fluctuating temperature conditions, thereby identifying a clear gene target for future potato breeding strategies.

Root traits for a changing physical environment

Tracy A. Valentine, A. Glyn Bengough, Paul D. Hallett & Blair M. McKenzie

With increasing constraints on the use of fertilisers and irrigation water worldwide, crops need root systems better able to grow in soils containing limited water and nutrient resources. Plants must be able to place their roots close to where these resources are located in the soil profile. We have been studying how plant genotype influences the growth and distribution of its roots, at scales from the laboratory to the field, with a view to developing better ways of identifying, and ultimately screening for, desirable root traits. Another equally important aspect is evaluating the physical restrictions to root growth that occur in a range of soil types, so that factors limiting root growth can be quantified and used to identify the most important physical restrictions throughout a field season. This information will be used to develop improved soil management practices and the breeding of plant varieties suited to particular soil conditions.

In a recent survey of more than 50 farms in the east of Scotland we found that, even when soil water availability was close to optimal, nearly 40% of soils had strength sufficient to mechanically impede root growth. Seedling screens confirmed that soil physical conditions were limiting root elongation to less than half of the unimpeded rate in a similar percentage of sites examined. The impact of changes in climate and

Figure 5 The influence of genotype and interaction with the environment in the ability of barley plants to access subsoil water, leading to differences in plant height and potentially crop productivity.

farming on plant and crop performance will depend not only on the severity of these physical limitations to roots, but also on the frequency, duration, and timing of these limitations. Rainfall patterns are predicted to become more erratic due to climate change and may result in more frequently waterlogged soil while at other times periods of drought may result in increased soil strength. Changes in farming such as decreasing tillage to save fuel may adversely affect soil conditions. Soil compaction, particularly of the subsoil, could be exacerbating the limitations to root growth.

We have developed techniques to study the spatial distribution of the roots of both seedlings and more mature plants. The angular spread of seedling cereal roots, measured in two dimensions using a gel plate screen developed at SCRI has been found to relate

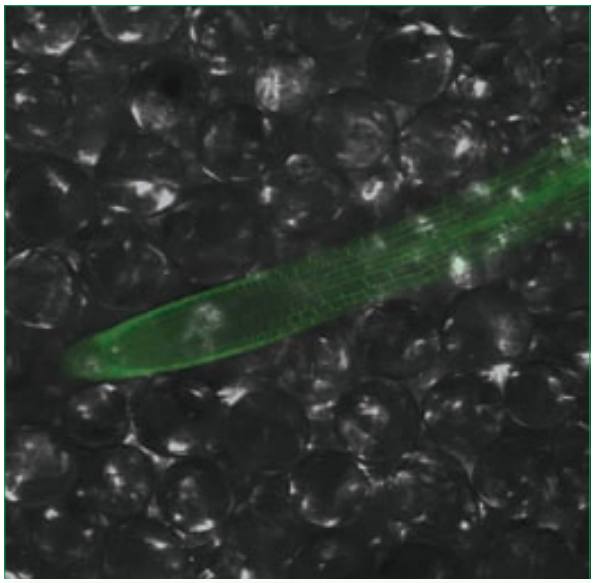

Figure 6 Root tip behaviour under physically inhibiting environment: Live imaging techniques of plant–environment interactions in a model system using fluorescently labelled roots and glass beads.

closely to root spread and water extraction by mature drought tolerant cereal plants. The angular spread of roots in two dimensions from a range of contrasting genotypes was also found, by X-ray tomography, to relate closely to root spread in three dimensions. We have also developed a field method for screening the ability of crop genotypes to access subsoil water, and this is demonstrating both the influence of genotype on this root trait and the importance of deep root growth even relatively early in the growth of spring sown barley (Fig. 5). The importance of root tip traits in the ability of roots to overcome soil physical restrictions is being explored at the individual plant and individual root tip scales using live imaging techniques (Fig. 6) and by linking to root growth models of soil exploration. Mechanisms used by roots to overcome stress, such as producing a lubricating layer or changing the properties of soil, are a major component of our research in this area.

Risks of new or emerging pests and pathogens posed by environmental change

Lesley Torrance, Ian K. Toth, David E.L. Cooke, Brian Fenton, Vivian C. Blok & Alison K. Lees

Environmental factors greatly influence the incidence and geographical distribution of pests and diseases. The availability of a susceptible host together with optimum conditions of temperature and humidity are major factors in determining whether a pathogen can establish in a new location. Adaptation to the predicted environmental changes will affect Scottish agronomic practices as well as the spectrum of non-crop species grown. Some examples of the likely changes in pests and disease threats to potato production in Scotland and the research being done to counter these threats are discussed.

Virus diseases are the major cause of seed potato degeneration causing down-grading of seed crops. Aphids transmit viruses from plant to plant (Fig. 7) and transmission early in the season has a major effect on virus incidence in the harvested tubers. Scotland has an effective aphid monitoring programme and this

has shown that some of the main virus vector aphids are appearing earlier, when they could be spreading viruses. If this trend continues it may change the areas of Scotland with a natural advantage for production of healthy seed potatoes and require earlier applications of insecticides. In collaboration with industry we are conducting research to establish effective aphid-borne virus control strategies. However, the most effective long term disease control is achieved through resistant crops and we have found a new source of extreme resistance which is effective against three important aphid transmitted Potyviruses (PVY, PVA, PVV). Current research is focused on developing molecular markers which can be used to deploy the resistance in breeding programmes. *Phytophthora infestans,* the cause of late blight, has been shown to be a highly adaptable pathogen that can respond rapidly to changing environmental conditions and overcome major host resistance genes. Late blight will pose a continuing threat to Scottish crops. Aided by the recently published whole genome sequence, we are making major advances in understanding the function and evolution of *P. infestans* pathogenicity factors. We are also generating valuable data on the response of the current pathogen populations to moisture and temperature criteria which are relevant to current and future prediction and control of late blight in Scottish crops. Adaptation of the potato cyst nematode (PCN)

Figure 7 Aphid virus vector.

to environmental changes and the potential for higher multiplication rates are also being examined. The risks of hatching and completion of a second generation during the growing season and the potential for selection of populations with faster generation times are being assessed in relation to integrated management of PCN.

Figure 8 *Dickeya solani* on ware potatoes cv Agria imported to UK from Spain. Tubers show Cheesy Rot and breakdown of the vascular ring (very similar to that of Ring Rot).
Picture supplied by Eric Anderson (Scottish Agronomy)

Figure 9 *P. kernoviae* infection of rhododendron.

Threats from non-indigenous diseases include the introduction by contamination of infected planting material, e.g., the bacteria *Dickeya dianthicola* and *D. solani* (formerly *Erwinia chrysanthemi*) on potato tubers (Fig. 8) and the nematode *Meloidogyne chitwoodi* in adherent soil particles. These pests and pathogens have been intercepted on potato seed tubers and are currently responsible for major disease losses in Europe. We have rapid and sensitive diagnostics to detect *M. chitwoodi* and are working with SASA (Science and Advice for Scottish Agriculture) and FERA (The Food and Environment Research Agency) to develop similar diagnostics for *Dickeya.* These diagnostics are important for monitoring the movement of these pests and pathogens, and complement our work on the biology of the diseases they cause.

Environmental change will also alter the spectrum of plants growing in natural, semi-natural ecosystems and gardens in Scotland. Associated threats from invasive pathogens are thus also being studied. In a collaborative project on *P. ramorum* and *P. kernoviae* (Fig. 9) knowledge and molecular markers derived from research on *P. infestans* are being used to assess the risks posed to Scottish heathland ecosystems.

These examples are just a few of the many threats that will face agricultural production systems now and in the future. Our work provides robust evidence and analysis to advise policy makers in Scottish Government and the private sector to help combat these threats. An outcome of this work suggests that a re-evaluation of the current operation of the ‘Safe Haven’ certification scheme to protect Scottish seed potatoes is worthwhile.

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Biodiversity

Robbie Waugh

Biodiversity describes the variation of life forms that exist within a population, a species, an ecosystem or a geographical region. Measures of biodiversity are frequently used to assess the health of a 'biological system' and although commonly associated with conservation biology, biodiversity research has broad application in plant and environmental sciences. It provides a framework for understanding and quantifying the molecular variation in individual genes and the richness of species in complex ecosystems, and may guide management interventions to maintain or enhance the viability of both species and communities. Biodiversity is the driving force of evolution, and its efficient exploitation is the basis of crop plant improvement. Not surprisingly then, across SCRI, considerable energy is being expended on the quantification and interpretation of biodiversity to address a wide range of biological questions.

Here we provide four examples of biodiversity research being conducted across the research programmes. In the first, Joanne Russell and colleagues show how a clear relationship exists between genetic distances and geographic distances among populations of barley landraces and discuss how these observations shape our understanding of the domestication and evolution of the species, with potential implications for plant breeding. By walking through an example project, in the second, Iain Milne and colleagues illustrate how the visualisation tools they have developed have become essential components in the analysis of highly complex molecular diversity datasets. Ali Karley and colleagues then describe how interactions between insects and microbes can shape interactions between herbivores and other components of an agroecosystem while, in the final contribution, the importance of understanding pest and pathogen diversity is described by Alison Lees and colleagues. These serve to illustrate the breadth of activity being conducted under the biodiversity banner.

Relationship between genetic distances and geographic distances among populations of barley landraces

Joanne R. Russell, Ian K. Dawson, Allan Booth, Andy J. Flavell[1], Brian J. Steffenson[2], Eva Weltzien[3], Salvatore Ceccarelli[4] & Robbie Waugh

Within barley an enormous amount of natural diversity exists, which has been shaped by the processes of domestication, cultivation and breeding. Different views have been proposed about the domestication of barley, with some authors stressing a single origin in the Fertile Crescent and others suggesting more complex domestication events. One of the most effective means of understanding the origins of domestication and cultivation is by comparative sampling of wild and cultivated accessions from regions where their ranges overlap. We have assembled and studied a collection of approximately 500 stratified, geographically referenced and matched samples of landrace (cultivated) and wild barley from across Jordan and Syria (Fig. 1). We used a high resolution genotyping platform that provides accurate measures of molecular biodiversity across the entire barley genome to explore the origins of barley cultivation. We observed clear

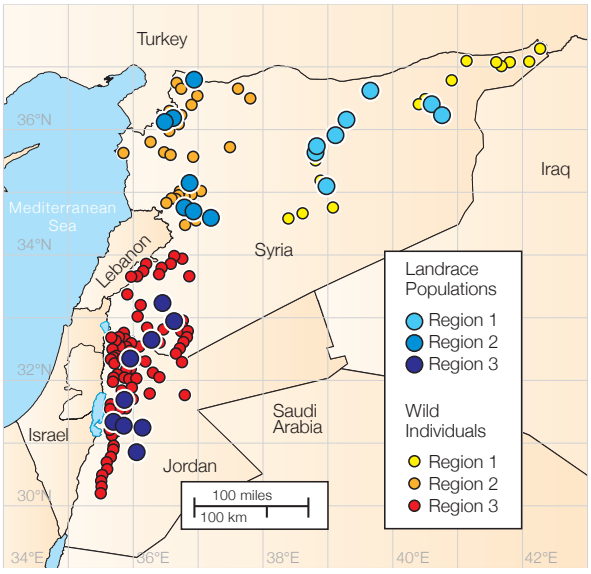


Figure 1 Geographic locations of sites in Jordan and Syria from which landrace and wild barley accessions were sampled for an analysis of SNP variation. Twenty-four landrace populations, comprising 317 accessions in total and 131 individual wild plants differentiated into three geographical regions: Region 1, North-eastern Syria; Region 2, North-western Syria; Region 3, Jordan and southern Syria.

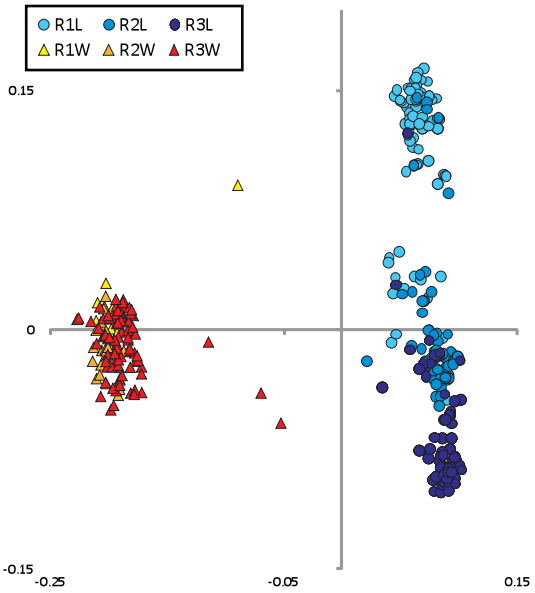


Figure 2 Principal coordinate analysis for 1135 SNP loci in landrace (*N* = 317) and wild (*N* = 131) barley accessions sampled from Jordan and Syria. Landrace and wild accessions were clearly differentiated, except for four 'wild' individuals that placed unusually in ordination. The first principal axis (horizontal) accounted for 35% of all variation, the second principal axis (vertical) for 13%. For information on sample designations see Fig. 1.

evidence for geographic structuring of genetic variation in both wild and landrace barley (Fig. 2). Differentiation was however less pronounced in wild barley. Three geographical regions were clearly identified and cross comparisons indicated that landrace populations from all three regions were most similar to wild material from Jordan and south Syria. An important observation is that landrace and wild accessions were 'not-matched' in north-western and north-eastern Syria, as would have been anticipated if cultivated material was of local origin. At the same time, a high degree of structuring in landrace accessions suggests that these cultivated stands have been present at their current locations for a considerable period of time. This distinctness has been maintained in spite of human exchange of germplasm that could potentially swamp any pre-existing landraces and suggests strong pressure towards local adaptation to varying environmental conditions in the two countries.

Gene flow between cultivated and wild populations after domestication has been suggested as an important mechanism for adaptation in barley and has been

[1]University of Dundee, [2]University of Minnesota, [3]ICRISAT, [4]ICARDA

proposed to be relatively common. Our analysis highlighted four unusual 'wild' individuals consistent with minor directional interaction between wild and landrace barley (Fig. 2). However overall, landrace and wild material act essentially as independent entities despite geographic overlap. This may reflect variation in flowering time and maturity, with the brittle rachis of wild barley meaning that in mixed stands wild heads will shatter and seed be dispersed before the cultivated seed is collected. This research provides insight into the process of domestication of barley in the Fertile Crescent. Comparisons of the observed patterns of molecular diversity in this material with that in advanced cultivars will help identify chromosomal regions that have been subject to human and environmental selection during the process of domestication.

Visualising genetic diversity

Iain Milne, Paul Shaw, Linda Milne, Micha Bayer, Gordon Stephen & David F. Marshall

The increasingly complex data sets generated through new DNA sequencing and genotyping technologies, such as described above for barley, require a new generation of software tools to aid analysis and interrogation. The sheer volume of data imposes limitations on our ability to inspect the results of analyses and look for patterns that reflect either quality control issues or biologically meaningful structure in the data. Therefore, to support and enable analyses of genetic and genomic data we have developed a suite of computational visualisation and analysis tools. To illustrate their value, in this report we follow a typical project that starts with the discovery of single nucleotide polymorphism (SNP) markers, is followed by their use for genotyping to assess patterns of diversity in germplasm collections, and ends with comparative genomics – an approach used to identify putative regional gene content.

The process starts with using second generation sequencing technologies to sequence the transcriptome from two or more plant lines from any plant species. The output of this exercise, more than 1,000,000 individual sequences, are either aligned against an existing sequence (such as an Expressed Sequence

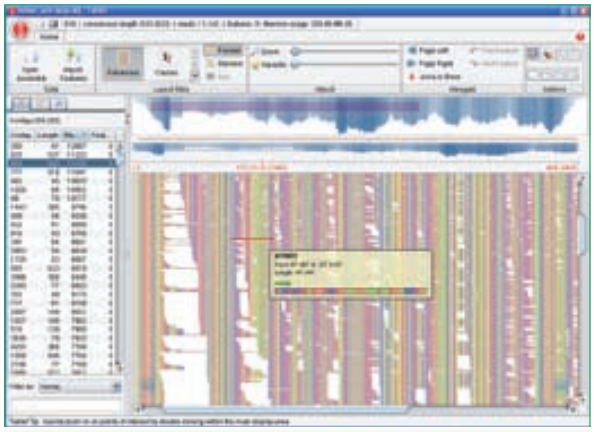


Figure 3 *Tablet* displaying an assembly of singletons that are left over from a *Mosaik* mapping of barley read using Solexa technology from seven different barley lines.

Tag assembly) or assembled (i.e. joined together into longer contiguous sequences) *de novo*. The output may result in more than 50,000 assembled transcripts, which can be analysed for polymorphic nucleotide sites that are then 'marked up' as potential SNPs. These assemblies can be visualised with *Tablet* (Fig. 3), software we specially designed to cope with this scale of data, allowing us to view and navigate the millions of aligned DNA fragments and identify which SNPs are most suitable for translation into high-throughput SNP genotyping assays.

The resulting avalanche of high-quality genotypic data presents us with new challenges in data maintenance and analysis. In collaboration with colleagues at the University of Dundee we are developing a new implementation of our existing marker database

Figure 4 160 SNPs from chromosome 6H of barley are displayed within *Flapjack*, where multiple graphical views allow us to visualise the associated genotype, phenotype and QTL data simultaneously.

Figure 5 *Strudel* rendering homologous mappings between high-density linkage maps across multiple genomes of *Brachypodium*, barley and rice.

infrastructure, *Germinate 2,* to cope with these demands. *Germinate 2* allows us to store, query and visualise a broad range of associated information, including passport data, trait information, pedigrees and the results of analyses. We developed *Flapjack* (Fig. 4) – a revolutionary new graphical-genotyping and manipulation tool – to visualise the genotype data from many thousands of lines at many thousands of SNPs, and we are working with collaborators around the world to ensure that *Flapjack* is compatible with major new genotypic data sets from maize, rice and *Arabidopsis* as well as genetic analysis and simulation packages.

High-throughput genotyping technology enables us to rapidly identify key genomic regions that control agriculturally important traits through either conventional Quantitative Trait Loci (QTL) analysis or association analysis. But we want to identify genes – not regions. Comparative mapping is facilitated by our visualisation tool *Strudel* (Fig. 5), which enables the rapid identification of the gene content of orthologous genomic regions (derived from a common ancestor) across multiple species. In addition, *Hordeum Relator* visualises the relationships between DNA sequences from various species related to barley, including rice, *Brachypodium*, oat and sorghum. Based on this set of integrated databases, web resources, and Java desktop applications, our software – although primarily developed to meet the needs of ourselves and our collaborators – is made freely available to all, and is used by researchers in over 40 countries around the world.

Insect herbivore–microbe interactions: impacts on insect fitness and behaviour

Ali J. Karley, Scott N. Johnson, Emily Clark & Lindsay S. McMenemy

Insect herbivores are key components of agroecosystems, both as consumers of crop and non-crop plants and as a food source and host for a wide range of natural enemies. Interactions between insects and microbes often shape how insect herbivores interact with other parts of the system. In particular, microbes are frequently harboured or transmitted by insect herbivores and fulfil a range of roles as symbionts, parasites or pathogens. We study the biology of plant sap-feeding aphids to unravel the complex interactions between insect herbivores, their bacterial symbionts and the plant viruses that they transmit, to determine the role of microbes in regulating insect populations in agroecosystems.

Many herbivorous insects possess microbes known as symbionts that live within the insect and perform vital functions that are essential for insect survival. In aphids, most species harbour a 'primary' bacterial symbiont, *Buchnera aphidicola*, which lives in specialised organs within aphid tissues and produces amino acids that the aphid cannot produce. Aphids can also harbour one or more types of 'secondary' bacterial symbiont whose functions are less certain. There is increasing evidence that these secondary bacteria play a significant role in aphid interactions with other organisms, particularly by altering aphid susceptibility to natural enemy attack. In the Cabbage aphid (*Brevicoryne brassicae*), we have identified different bacterial types, split into two dominant groups (Group 1 and Group 2), in aphid lines collected from Fife, Tayside and North Yorkshire. We have developed quantitative molecular methods to determine the relative abundance of secondary bacteria associated with the Cabbage aphid and shown that frequency of Group 1 and Group 2 secondary bacteria compared to *Buchnera* is variable between aphid lines. Experimental work indicates that Group 2 bacteria are associated with reduced aphid fecundity (Fig. 6a) and with increased egg production in emerging *Diaeretiella rapae*, the hymenopteran wasp species that parasitises cabbage aphids (Fig. 6b). Changes in aphid fitness associated with the presence of particular secondary bacteria types are likely to affect the ability of aphids to act as vectors of plant pathogens.

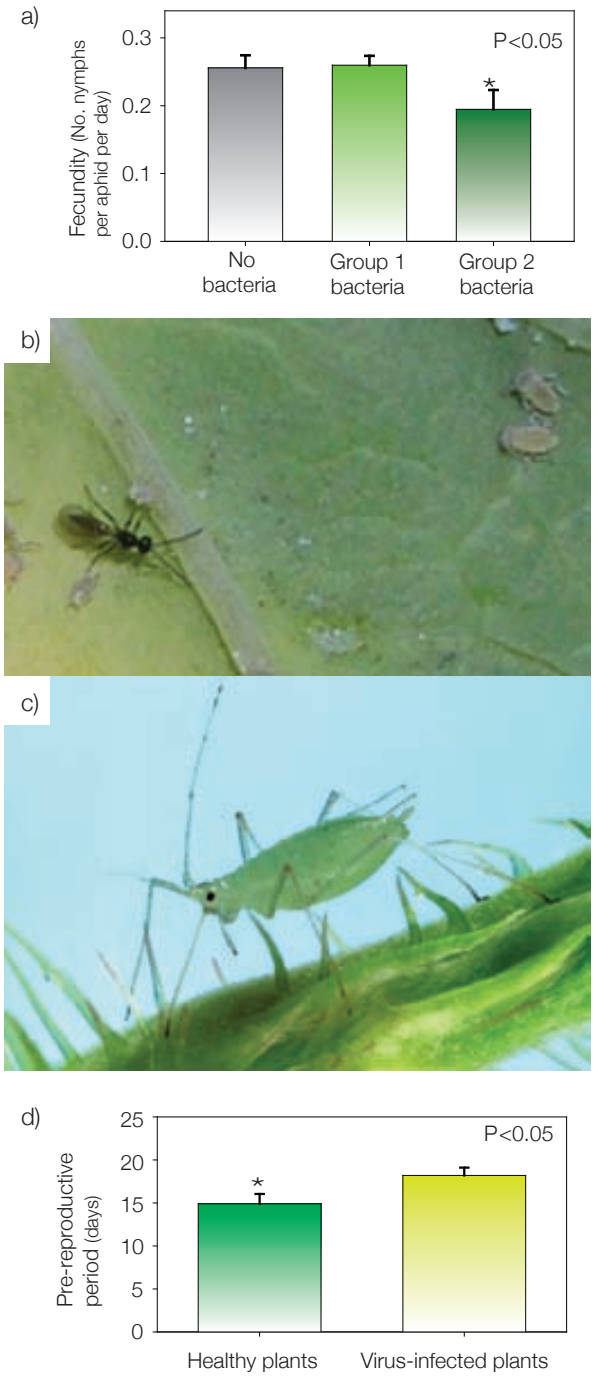


Figure 6 a) Impact of secondary bacteria on reproduction by the Cabbage aphid, *Brevicoryne brassicae.* b) The hymenopteran wasp *Diaeretiella rapae* together with Cabbage aphid nymphs. c) Large raspberry aphid, *Amphorophora idaei.* d) Impact of RLSV infection on large raspberry aphid pre-reproductive period.

Moreover, plant pathogens themselves can change plant chemistry in a way that makes crops more attractive to insect vectors. We have shown that the large raspberry aphid, *Amphorophora idaei* (Fig. 6c), preferentially colonises plants infected with one or more of the viruses it vectors, such as *Raspberry leaf spot virus* (RLSV). However, the plant virus impairs aphid performance by slowing its development so that the time taken by the aphid to start reproducing, the pre-reproductive period, is extended (Fig. 6d). This developmental delay may cause the aphid to disperse from the plant soon after initial colonisation, thereby facilitating the spread of the plant pathogen. Thus, characterising how microbes influence insect herbivores in arable and horticultural crops is providing us with an insight into how we might exploit ecosystem processes to ensure productive systems and maintenance of biodiversity.

Understanding pathogen biodiversity as a key to controlling crop diseases

Alison K. Lees, David E.L. Cooke, Brian Fenton & Adrian C. Newton

Crop pathogens and pests are an unwelcome but important component of the biodiversity found in managed ecosystems. They are diverse and adaptable, meaning that they are able to respond quickly to disease management practices and changing climate and therefore to reduce agricultural sustainability. Evolution of pests and pathogens, and the migration of new invasive species, leads to a constantly changing threat to crop production. In particular, the ability of pests and pathogens to overcome genetic resistance that has been bred, or engineered, into crops and the development of resistance to agrochemicals is problematic. Our work seeks to understand these threats, and the factors that drive population changes, with the goal of effective disease management. We illustrate this approach by discussing examples of our work on three very different host–parasite interactions. In each case we have developed and used DNA fingerprinting methods (microsatellite markers) to allow us to monitor and understand diversity.

Phytophthora infestans (Fig. 7) is the cause of potato late blight which results in serious reductions in yield and quality of ware and seed potato crops on a global scale. By monitoring several thousand isolates of *P. infestans,* sampled predominantly from commercial crops, we identified a dramatic shift in the UK population with an increase in the frequency of a particularly aggressive A2 mating type strain that is able to overcome some sources of host resistance. The implications of the changes have been reported to the potato industry and management practices altered accordingly.

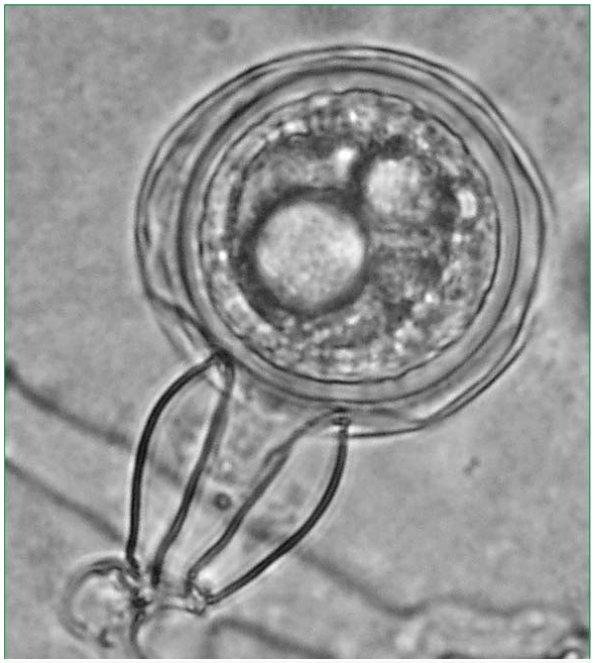


Figure 7 Image of an oospore of *Phytophthora infestans* – a long lived soil-borne survival structure which is a source of increased biodiversity in the population.

The fungal pathogen *Rhynchosporium secalis* causes 'rhynchosporium' or 'scald', the most problematic disease currently challenging sustainable barley production. Major genes for resistance to *R. secalis* in barley varieties are readily overcome, but partial resistance genes can provide effective resistance in the field. *R. secalis* is being monitored to understand how populations change in response to use of varieties with major resistance genes, partial resistance, and even non-symptomatic resistance and how barley variety mixtures affect population structure. Studies so far show that *R. secalis* is clearly a very variable pathogen with a very high capacity for adaptation.

In addition, natural variation in the *P. infestans* and *R. secalis* genes that govern the ability of the pathogens to infect and cause disease is being investigated so that the likely durability of corresponding resistance genes in the potato and barley gene-pools can be inferred, thus making efficient use of host biodiversity.

The peach–potato aphid is an important vector of potato viruses and can readily adapt to insecticides.

In a parallel situation to late blight we have followed the relative success of different genotypes each year and have shown that a single genotype, or clone, denoted type O, has come to dominate the UK population almost certainly due to the presence of a mutation causing resistance to dimethyl carbamate, a very commonly used insecticide. As the growth rate of clone O is no better than other genotypes (Fig. 8) it is also likely to have maintained good defences against attack by parasitoids in the field. Aphid genes are responsible for this phenotype as these *M. persicae* have no secondary symbionts. It appears that, like the potato plant itself its pests and pathogens effectively use asexual reproduction to multiply well adapted gene combinations.

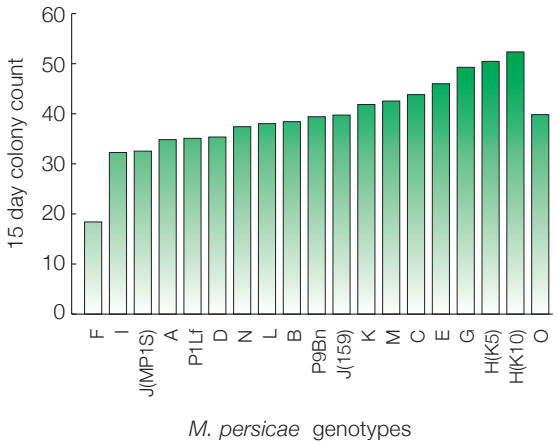


Figure 8 Variation in growth rate of different *M. persicae* genotypes (as characterised using SSR markers) measured as number of individual aphids per colony after culture on oilseed rape for 15 days.

Perspectives

As illustrated above, it is clear that agriculture faces many challenges to sustain production as climatic zones shift and changes to agricultural systems accelerate. Consequently, new biotic and environmental stresses continually threaten crop production. A solid understanding, continued monitoring and appropriate use and/or management of biodiversity, from genes to agroecosystems, will remain a key component of agriculture's ability to adapt.

scri
living technology

Wealthier & Healthier

Derek Stewart

A combined objective that is key to the development of a vibrant sustainable Scottish economy is the generation of food that creates wealth while being healthier and safer. The Scottish diet has long been held up as the worst in Europe, with Scots regularly topping the tables of degenerative disease such as cardiovascular disease, cancer etc. However, the national diet has improved with a commensurate reduction in disease levels, and through several national and international projects we aim to continue this trend. For example, as part of the EU-funded project, DEVELONUTRI, we are aiming to identity the points throughout the potato, tomato and wheat food chains at which nutritive value is lost.

In addition, we are also trying to enhance the value of our staple foods such as bread by substituting a proportion of the wheat with barley. Barley is one of the few crops that has led to a product with an approved health claim due to the natural component β-glucan which – if present in the diet at ~4% – can lead to a reduction in the risk of cardiovascular disease. This project, BarleyBread, was funded by the EU and involved interaction with SMEs across Europe including the Scottish food ingredients company, Macphie of Glenbervie Ltd, who generated trial breads which were hugely successful in consumer trials. Work on crop nutritional value and human health benefits is also being pursued in soft fruit such as blackcurrant, raspberry and other related crops.

The following articles show that our research into wealthier, healthier and safer food encompasses science from the fundamental through to the applied, and highlights our ability to translate this through to products.

Understanding the genetics of raspberry fruit quality for improved consumer appeal

Julie Graham

Berry sales in the UK are now second only to those of apples, accounting for 19% of all fruit sold. Just under 33% of consumers now purchase raspberries (estimated retail value £125.7 million). Currently one week's raspberry sales are equivalent to what would have been purchased in a whole year six years ago. This success of the raspberry industry is due in part to commercial raspberry production having been revitalised by new horticultural strategies, specifically protected cultivation. Protected cultivation has been pivotal in the success of UK berry cultivation, and experiments at SCRI and in Blairgowrie have demonstrated significant increase in all quality parameters from tunnel grown raspberries. Predictions are for even greater increases given availability of appropriate high quality varieties that meet market requirements across a wider season.

Consumers are willing to pay a premium for quality raspberries and health would benefit from increased consumption. The most important factor for improvement in eating quality is flavour or specifically taste, made up of sweetness and sourness and the balance of these two attributes and overall intensity of flavour with impacts from flavour volatiles. However, appearance is as important as taste for initial consumer selection, as only berries of high visual quality will be purchased. Berry size and colouration are key to consumer success here. Consumer disappointment, given a high price for raspberries, discourages repeat purchases.

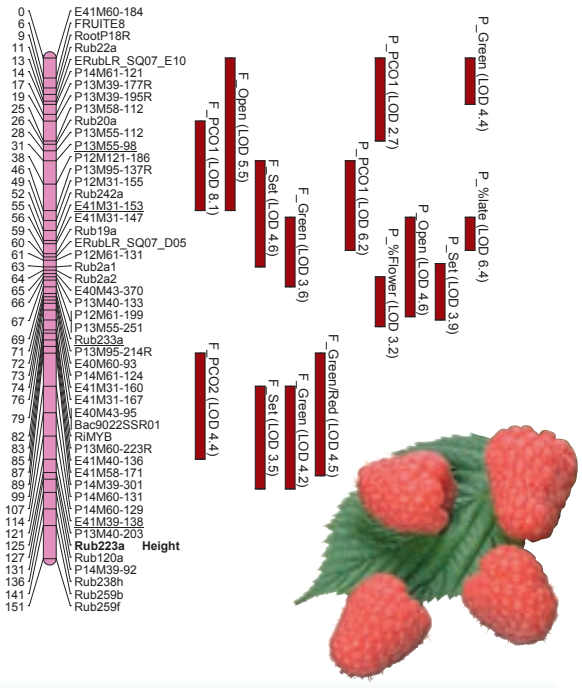


Figure 1 Chromosomal regions controlling fruit development and quality.

Breeding new high quality raspberries which can be scheduled across a wider season is a long, difficult process hampered by several genetic problems. Concern over environmental impact and sustainability of agricultural and horticultural practices is leading to a greater emphasis on pest and disease resistance, as well as the ability of plants to withstand local environmental stresses. The changes in environmental, cultural and agronomic practices within the industry will impact strongly on the nature of the germplasm required for the future, with a greater interest in the conservation of genetic resources and utilisation of diverse locally adapted germplasm. Breeding methods used in raspberry have changed very little over the last 40 years and little novel germplasm has made its way into commercial cultivars. However, with the narrowing genetic base coupled with the increasing demands from consumers, new breeding methods are required to meet demands. The speed and precision of breeding can be improved by the understanding of the genetic control of key traits and then the deployment of molecular tools or markers (linked to good traits) for germplasm assessment and management. The correlation between traits and chromosomes is done by developing linkage maps which represent the plant chromosomes with locations of markers and traits placed along them. Implementation of marker assisted breeding which links easily scorable molecular markers to complex traits which require extensive field evaluations, can yield defined improvements in fruit quality across the cropping season in harmony with developments of disease resistances and production agronomic traits. In the raspberry this is now possible through the development of the SCRI raspberry genetic map that forms the basis for linking phenotype

(plant traits) to genotype (plant genes). A number of chromosomal locations (quantitative trait loci [QTL]) for key quality traits in raspberry have been identified and in some cases the major genes responsible for trait variation have been identified (Fig. 1). These include steps towards understanding the ripening process which is essential to enable the development of high quality varieties fruiting across a wide season. Chromosomal locations responsible for ripening have been identified. A number of key genes including a MADS-box gene and Gene H were associated with the QTL and markers associated with plant height have also been identified. The major anthocyanin pigments in red raspberry have also been mapped to the same chromosome region on linkage groups (LG) 1 and 4 across years and from different environments. The most significant markers were genes including bHLH, and bZIP transcription factors which are thought to regulate the anthocyanin pathway. Colour has also been assessed with progress made in understanding the major genetic and environmental control. Sensory traits and the composition of fruit, both of which influence flavour, have been studied and again preliminary chromosomal regions for control identified. Methods have been developed that will allow us to measure and subsequently understand the genetic regulation of health components for improvements through marker assisted breeding.

Progress in the area of the genetic regulation of fruit quality is well underway, with marker assisted breeding now possible for a number of quality traits which can be transferred into conventional breeding programmes for targeted and timely improvements.

Fruit components and their impact on fundamental disease mechanisms

Gordon J. McDougall

The health benefits associated with a diet rich in fruit and vegetables may be derived from the intake of natural phytochemicals. One theory suggests that polyphenol antioxidants (which are especially high in fruits and berries) protect against oxidative damage

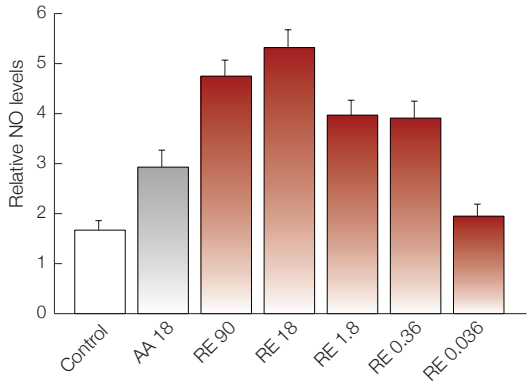


Figure 2 Protection of nitric oxide levels in a rat model by berry extracts. AA = ascorbic acid, RE = raspberry extracts. All values are µg/ml.

involved in disease development. However, many polyphenols (e.g. anthocyanins) are poorly bioavailable and are unlikely to act as antioxidants at the cellular level. Indeed, large portions of berry polyphenols are not taken up into the blood and remain in the gut.

Nevertheless, evidence continues to accrue that berries or polyphenol-rich berry preparations can influence the progression of neurodegenerative diseases, cancers, cardiovascular disease and diabetes *in vivo* even if an overarching theory to explain their mechanism of action has not been formulated. We present evidence that berry polyphenols have bioactivities (often independent of their antioxidant capacity) relevant to cardiovascular health, obesity and glycaemic control.

Nitric oxide is a key signalling molecule which controls vasodilatory responses in blood vessels. Raspberry extracts (at 90 - 0.36 µg/ml) significantly increased nitric oxide levels in a rat model system and were more effective than ascorbic acid, a known cardio-protectant (Fig. 2). Protection of nitric oxide levels, presumably through an antioxidant mechanism by reducing free radical degradation, could influence cardiovascular fitness *in vivo*. Such model studies are backed by studies which highlight the cardiovascular benefits of berry intake.

Slowing the rate of digestion of starch rich foods could influence post meal blood glucose levels and glycaemic control, thereby benefiting type II diabetes. In model

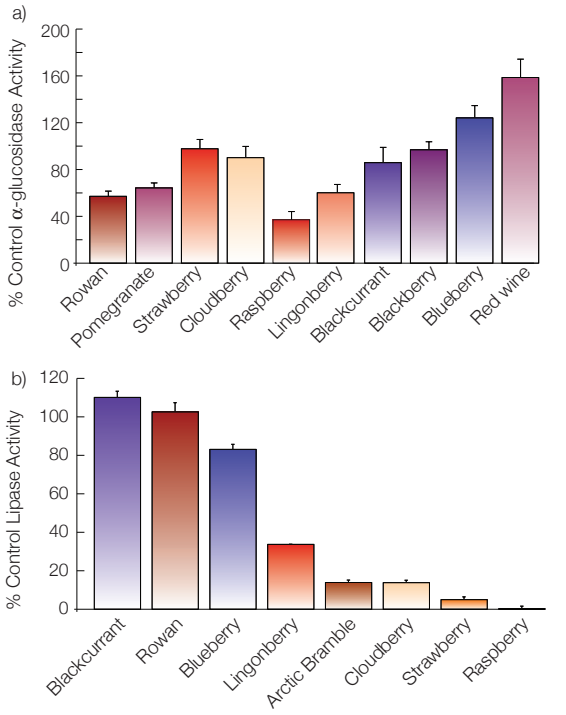


Figure 3 a) Inhibition of α-glucosidase activity by berry extracts. b) Inhibition of lipase by berry extracts. All extracts assayed at 50 µg/ml.

systems, polyphenol extracts from berries inhibit α-glucosidase, the key enzyme in glucose release from starch, at doses easily achievable from normal dietary intake (Fig. 3). Inhibition of α-glucosidase is the target for acarbose-type pharmaceuticals (e.g. Glucobay) which are currently prescribed to type II diabetics to reduce starch breakdown after meals. Identifying the active polyphenol ingredients is under further study.

Inhibition of fat digestion could reduce blood lipid levels and calorie intake from fat rich meals and benefit cardiovascular complications and directly influence obesity. In model systems, polyphenol extracts from berries inhibited pancreatic lipase, which is the key enzyme for fat digestion (Fig. 3). Inhibition of this enzyme by drugs, such as orlistat (Xenical also sold as Alli), is a current treatment for reducing obesity. Inhibition of lipase and reduction in blood lipid levels may explain the effects of berries on obesity in animals. The large differences in effectiveness of the berry extracts indicate that particular polyphenol components are more effective.

Derek Stewart and a tasting panel at work.

Selenium biofortification of bread

Philip J. White

Selenium (Se) is an essential mineral element for human nutrition. It is incorporated into several important proteins as the amino acid selenocysteine. Among these proteins are iodothyronine deiodinase, which is responsible for converting the prohormone thyroxine to the active thyroid hormones; sperm-capsule selenoprotein, which is implicated in sperm motility; the antioxidant enzyme glutathione peroxidase; and selenoprotein P, the main Se-compound in plasma. According to the UK Food Standards Agency, "Selenium plays an important role in our immune system's function, in thyroid hormone metabolism and in reproduction. It is also part of the body's antioxidant defence system, preventing damage to cells and tissues".

The UK reference nutrient intakes (RNI = the dietary intake that meets the needs of 97.5% of the population) for adult males and females are 60 and 75 µg Se d^{-1}, respectively. However, the average dietary Se intakes in the UK have declined from over 60 µg Se d^{-1} in 1985 to between 48 and 58 µg Se d^{-1} today (Fig. 4). In Scotland, recent dietary surveys suggest that average dietary Se intakes may be lower than this. This downward trend is thought to be a consequence of replacing North American milling wheat, which is grown on high-Se soils and has a high Se concentration, with wheat grown on soils containing little Se in the UK. It has been suggested, therefore, that UK dietary Se intakes could be improved by increasing Se concentrations in homegrown milling wheat by applying Se-fertilisers to the crop. This practice is referred to as 'agronomic biofortification' and has been adopted

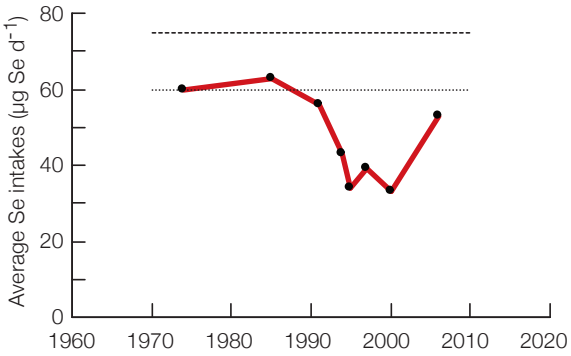


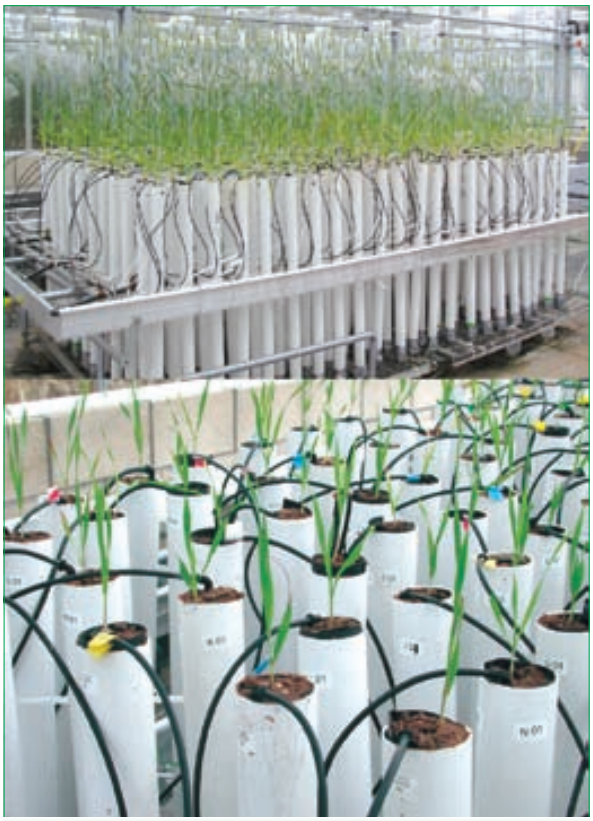
Figure 4 Average selenium intakes (µg Se d^{-1}) estimated from UK Total Diet Studies undertaken between 1974 and 2006. Horizontal lines indicate the UK reference nutrient intakes (RNI) for adult males (75 µg Se d^{-1}) and females (60 µg Se d^{-1}). Data sourced from the UK Food Standards Agency.

successfully in countries such as Finland. This year, the BAGELS consortium, which included Philip White from SCRI's Environment Plant Interactions Programme, have reported that the application of Se-fertilisers to UK wheat crops increases grain Se concentrations, and that Se concentrations in bread baked from this grain can be increased without affecting other quality attributes important for breadmaking.

BAGELS (Biofortification through Agronomy and Genotypes to Elevate Levels of Selenium; bagels.ukcrop.net) was a 'farm to fork' project sponsored by Defra through the Sustainable Arable LINK Programme. The partners spanned the entire food chain and included researchers, manufacturers and retailers. Partners included SCRI, University of Nottingham, University of East Anglia, Rothamsted Research, Institute of Food Research, Nickerson-Advanta, Velcourt, Carrs Fertiliser, Yara UK and Marks & Spencer. The main aim of the BAGELS project was to determine if the selenium levels of UK-grown wheat could be increased safely through the use of selenium-containing fertilisers, without causing harm to the environment. Field trials were conducted at the University of Nottingham, Rothamsted Research and Velcourt sites over two years on two widely-grown cultivars of Grade I bread-making wheat, Hereward and Solstice. These field trails demonstrated that the application of about 10 g Se ha^{-1} at the right time could increase grain selenium concentrations to levels similar to that of imported North

Harvesting a BAGELS field trial at the University of Nottingham. Photograph courtesy of Dr Martin Broadley.

American grain. The fate of the selenium applied in fertilisers was monitored in both the soil and the crop. Analysis of soils indicated that there was no residual build up of selenium in the soil that could pose an environmental risk. Analysis of the crop revealed that it acquired between 20 and 35% of the selenium applied in the fertiliser. About half of the selenium acquired by the crop remained in the straw, while half was recovered in the grain.



Glasshouse survey of genotypic variation in Se acquisition, Se redistribution within the plant, and grain Se concentration among wheat genotypes.

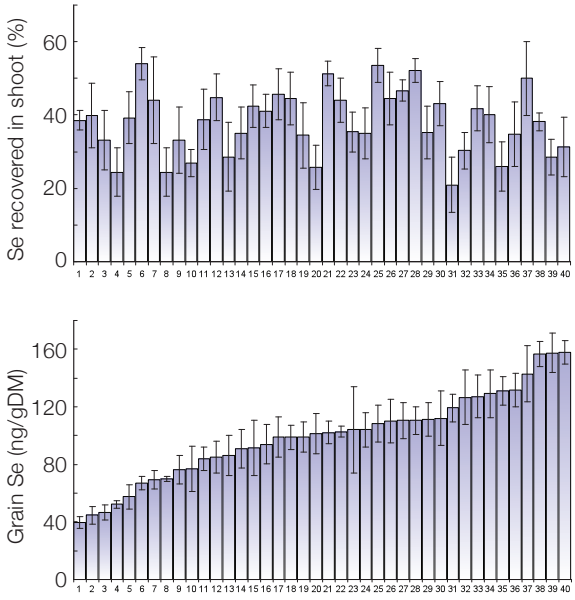


Figure 5 Genotypic variation in Se accumulation in above ground tissues, expressed as a percentage of the Se-fertiliser applied, and grain Se concentration among 40 cultivars of winter wheat grown in the glasshouse at SCRI in 2007/2008. (1) Dover, (2) Batis, (3) Opus, (4) Ochre, (5) Brompton, (6) Riband, (7) Isengrain, (8) Monopol, (9) Petrus, (10) Hereward, (11) Alchemy, (12) Lynx, (13) Mascot, (14) Malacca, (15) Zebedee, (16) Einstein, (17) Solstice, (18) Gatsby, (19) Deben, (20) Gladiator, (21) Rialto, (22) Hyperion, (23) Caphorn, (24) Cordiale, (25) Avalon, (26) Enorm, (27) A50-03, (28) PBIS, (29) Claire, (30) Scorpion 25, (31) Soissons, (32) Sokrates, (33) Gulliver, (34) Maris Widgeon, (35) Arche, (36) Robigus, (37) Flanders, (38) Cappelle-Deprez, (39) Glasgow, (40) ELS.

At present, Se-fertiliser is a non-renewable resource, and it has been estimated that if all of the world's wheat was fertilised at 10 g Se ha^{-1} then commercially viable Se reserves could be exhausted in less than 80 years. We must, therefore, use Se-fertilisers wisely. The efficient use of soil-applied Se-fertiliser by the wheat crop is determined by two physiological processes: (i) the acquisition of Se by the root system and (ii) the translocation of Se to the shoot and its accumulation in grain. At SCRI, we have surveyed genotypic variation in Se acquisition, Se redistribution within the plant, and grain Se concentration among 10 spring wheat and 40 winter wheat cultivars grown in a controlled glasshouse environment. Individual plants were grown in tubular plumbing pipes filled with a gravel:grit:sand mixture (40:40:20 by volume) fertigated with a complete mineral nutrient solution. A single application of sodium selenate was made during early vegetative growth, delivering 10 g Se ha^{-1}. Significant differences were

The biofortification of bread with selenium.

observed between wheat cultivars in their acquisition of selenium, selenium distribution within the plant and grain Se concentration (Fig. 5). There was a strong negative relationship between grain Se concentrations and grain yield. Since previous studies have shown that Se accumulation in grain is generally linearly related to the rate of Se-fertiliser application, one strategy to achieve target Se-concentrations in wheat grain would be to match Se-fertiliser applications to expected grain yields.

To determine the fate of selenium during processing, the concentrations and chemical forms of selenium in grain, flour fractions and bread products were analysed at the Institute of Food Research and University of East Anglia. The dominant organic form of selenium in wheat grain, flour fractions and bread products was found to be selenomethionine, which is readily bioavailable to humans. It was also observed that over 90% of the selenium present in the grain was retained in wholemeal bread. The application of 10 g Se ha^{-1} to the wheat crop produced loaves of white and wholemeal bread containing 6.4 and 7.1 µg Se per slice, respectively. Loaves baked from Se-biofortified UK wheat, in which one slice delivered approximately 10% of the RDI, were produced by Marks & Spencer for the Cereals 2008 Event.

In summary, the work of the BAGELS consortium has demonstrated that homegrown wheat can be biofortified with selenium through the agronomic application of Se-fertilisers, and that bread baked from Se-biofortified grain has the potential to increase dietary Se intakes in the UK.

Enterobacteria survival on plants: implications for food safety

Nicola Holden

Food-borne bacteria that belong to the Enterobacteria family are able to persist in a wide range of environments and colonise hosts from every kingdom. Among these are the zoonotic pathogens that are passed from animals to humans, including toxigenic *Escherichia coli* and *Salmonella enterica*. Although traditionally associated with their animal hosts, an increasing number of food-borne outbreaks of these pathogens have occurred as a result of contaminated fresh produce, for example, ready-to-eat bagged salads. Contamination can occur at several stages during production and processing. However, we and others have shown that the bacteria actively interact with plants and can colonise them as alternative hosts. Our research at SCRI aims to understand the mechanisms behind bacterial colonisation of plants with the long term goal of reduction of food-borne bacteria from fresh produce.

At the present time, the number of outbreaks from fresh produce is relatively small. However, there has been a steady rise in outbreaks over the past two decades

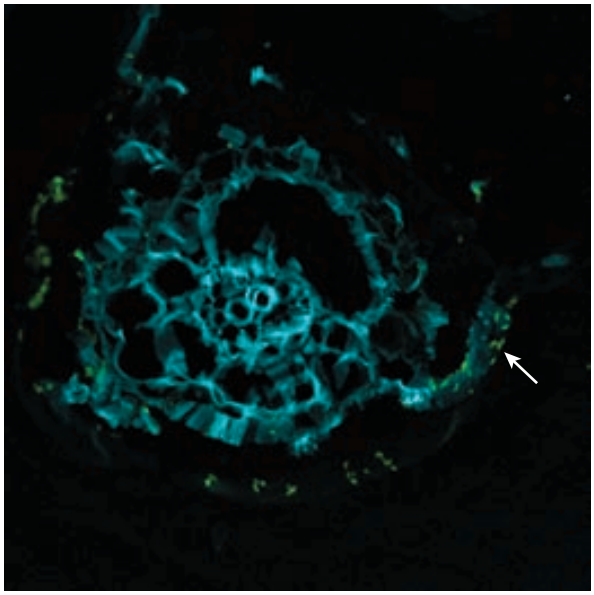


Figure 6 Microscopic image of a transverse section of a lettuce root that has been incubated with *Escherichia coli* O157:H7. The bacteria (in green) are located on the external tissue of the root (in blue) and can be clearly seen on a protruding root hair (arrowed).

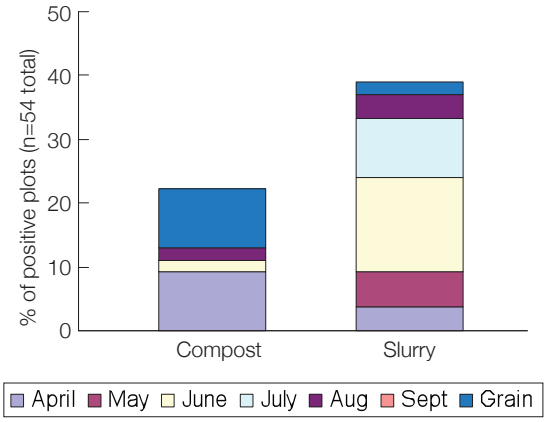


Figure 7 Presence of *Escherichia coli* isolated from the soil and barely grain of a barley trial site. The soil was amended with either municipal compost or animal slurry prior to sowing. Soil samples were collected on a monthly basis, barley grain post-harvest, and were analysed for the presence of *E. coli*-like bacteria. The number of plots, either treated with compost or slurry, that contained bacteria are expressed as a percentage of the total number of plots (n = 54).

or so, while the incidence from farm animal products is declining. Several of the reasons for the increase have been recognised and appropriate measures adopted to counteract their effect. Nevertheless, many fundamental questions remain to be answered on the interactions between bacteria and host plants and on the mechanisms of transmission from animal to crop.

Research at SCRI covers both areas. Firstly, in the processes that underpin bacterial colonisation of plants: how the bacteria initially interact with plants (Fig. 6); how colonisation becomes established; how the plants respond to the bacteria. It appears that specific interactions occur between the bacterium and plant host during the initial stages of colonisation, in a similar fashion to colonisation of mammalian cells. Work is continuing to elucidate the nature of the interaction, which appears to involve multiple factors. Another aspect of colonisation is internalisation of the bacteria from the external tissue of the plant to the internal tissue. Again, many fundamental questions remain to be answered about this phenomenon, such as the extent of internalisation and the cues that drive it. This has important implications for food safety where current practices only decontaminate the external parts of fresh produce.

The second area is the transmission of zoonotic bacteria from animal hosts to crop plants. We have investigated the effect of adding farm waste to cereal plots and found that it is possible to detect the bacteria throughout the growing season and at harvest time (Fig. 7). This reinforces the finding that these bacteria are perfectly able to adapt to conditions quite different from their animal hosts and shows the potential for long-term persistence in the soil. Collaborative work between Plant Pathology (Nicola Holden) and Environment Plant Interactions enables investigation of the bacterial populations on plants, which in turn, will aid in modelling the spread of the main food-borne bacterial pathogens in agriculture. This is particularly important in the context of climate change, which in addition to a direct influence on temperature and precipitation, has far reaching consequences for farming practices.

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Sustainability

Philip J. White

The future brings unprecedented challenges to agriculture. The world must produce sufficient nutritious food for its burgeoning population, despite global climate change, the exhaustion of its natural resources, and environmental pressures to reduce pollution, greenhouse gas emissions and chemical inputs (Fig. 1). Great changes in agronomy are required to meet these challenges and scientific research is necessary to inform these changes.

An increasing number of research projects at SCRI address agricultural sustainability, which is defined as the ability of a system to maintain stable levels of food production and quality in the long term, without compromising economic profitability or the environment. To achieve this, SCRI scientists are devising appropriate management strategies and developing novel crop varieties that will allow agriculture to preserve soil fertility, reduce chemical inputs, and optimise the use of water and fertilisers. The articles in this section illustrate aspects of SCRI's research towards agricultural sustainability.

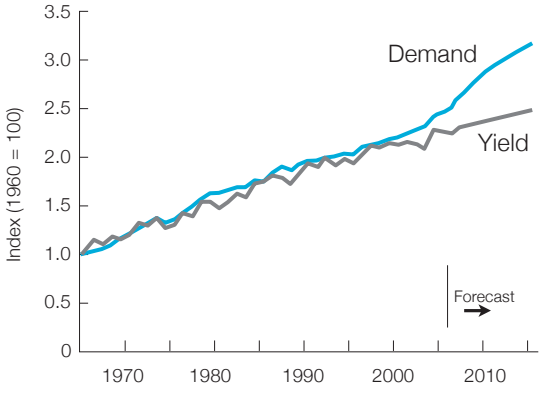


Figure 1 Trends in global demand and yield for food and feed. Data are from "Food, Feed and Fuels: An outlook on the agriculture, livestock and biofuel markets" by Jeffrey Currie, Goldman Sachs International, March 2007.

It is estimated that over one third of potential crop yield is lost to pests and diseases. Historically, these losses were minimised using agrochemicals, but recent legislation has removed from use over half the active substances controlling agricultural pests and diseases. Alternatives to agrochemicals, such as the development of resistant varieties or management practices that reduce the incidence and severity of pest or pathogen attack, are urgently required. John Jones and colleagues describe how basic knowledge

of the molecular interactions between plants and their pathogens can be used to identify genes that can be introduced into crop varieties to confer disease resistance, while Tom Shepherd and Nick Birch describe the use of biochemical signals to lure pests into traps. This research complements other work at SCRI, such as the development of monitoring tools, predictive models and biological control measures, which underpin integrated strategies for management of pests and diseases in sustainable crop production.

Another major challenge for crop production will be restrictions on irrigation water. Ankush Prashar and colleagues describe how physiologists and geneticists at SCRI are identifying traits that improve water use efficiency by the potato crop. Genetic markers for these traits can then be identified and used in breeding improved varieties. This work is one of several projects investigating agronomic and genetic strategies for the efficient use of water and fertilisers by arable crops, whose objective is to maintain stable yields with reduced inputs in the face of global change.

SCRI is putting theory into practice in the Centre for Sustainable Cropping – Balruddery. Here, six fields will become a long term experiment to test whether our knowledge of agronomy, crop physiology, soil and environmental processes, and integrated pest and disease management strategies can be used to develop a sustainable agroecosystem that will optimise inputs, biodiversity and ecosystem processes in addition to crop yield. The experiment will comprise a six year rotation that will be maintained over at least four cycles. The design will incorporate crop traits and agronomic practices that enable the reduction of water and fertiliser inputs, soil and weed management strategies that allow high yields while maintaining soil fertility and arable biodiversity, and environmentally benign and cost effective integrated pest and disease management strategies. Further aspects of the rationale and design of this ambitious experiment are summarised by Cathy Hawes and David W. Hopkins.

Functional analysis of pathogen effectors: how to go from genomics to durable resistance

Anna O. Avrova, Paul R. J. Birch*, Ingo Hein, John T. Jones & Leighton Pritchard

Pests and diseases cause extensive damage to crops and represent a threat to sustainable production. In Scottish agrosystems pathogens such as late blight (*Phytophthora infestans* – Fig. 2), potato cyst nematode (*Globodera*) and *Pectobacterium* on potato and *Rhynchosporium* on barley cause yield losses and require application of a wide range of pesticides. Although these pathogens use different mechanisms to infect plants, all need to produce a number of protein molecules, known as effectors, that interact with the plant to manipulate host processes to the benefit of the pathogen. Effectors may adjust plant metabolism so that nutrients are transferred to the pathogen, or may suppress host defences. Recognition of these effector molecules by host resistance genes triggers a strong local defence response that leads to resistance. The identification of pathogen effectors is therefore of key importance for understanding how pathogens infect plants and for identifying resistance genes that can be introduced into crop varieties.

The increased accessibility of high throughput sequencing tools means that genome and transcriptome sequencing is now achievable for a wide range of plant pathogens. Researchers at SCRI are part of the consortia that have sequenced or are sequencing the genomes of *P. infestans*, *R. secalis* and *G. pallida*. We have also sequenced the genomes of a range of bacterial plant pathogens including *Pectobacterium atrosepticum* and several species in the

Figure 2 *P. infestans* infected potato leaf.

*University of Dundee

Figure 3 Sequence logo indicating the relative frequency with which particular amino acids occur in the RxLR translocation motifs of *P. infestans* effectors.

genus *Dickeya*. Some of these recently defined *Dickeya* species are emerging as severe potato pathogens in the UK, possibly as a consequence of climate change.

Bioinformatics can be used to aid identification of pathogen effectors. Effectors within a pathogen may have conserved sequence motifs that are important for their function. For example, we have found that *P. infestans* effectors contain a conserved RxLR motif (Fig. 3) that allows them to be translocated into the host cell, and this motif can be used to identify novel candidate effectors from a genome sequence. We can also link bioinformatics to experimental evidence, such as expression analysis, to identify genes that are up-regulated as the pathogen infects the plant, or that are expressed in pathogen tissues known to be a source of effector molecules, in order to predict which genes may be effectors.

These approaches have allowed identification of effector gene families from all of the key pathogens that we work with. Bacterial effectors that are secreted through the Type III Secretion System have been identified, and some have been shown to suppress host defences. Over 500 predicted proteins containing the RxLR motif which is required for some oomycete effectors to enter host cells have been identified in *P. infestans*, and a number of these have also been shown to suppress plant defences. Effectors identified from *G. pallida* include a very large family of proteins (SPRYSECs) that may suppress host defences and that have been shown to localise to a range of plant subcellular structures (Fig. 4). Finally, a project in which the transcriptome of germinated conidia of *R. secalis* was studied has led to the identification of a large number of secreted proteins, including candidate effectors. The roles of these effectors in suppressing host defences are now being investigated within the Plant Pathology programme.

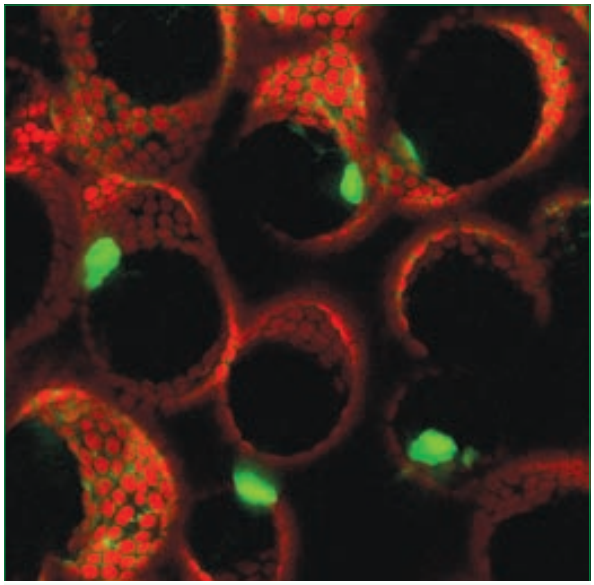


Figure 4 Subcellular localisation of a nematode effector to the nuclei of plant cells.

Although effectors play a role in suppressing the plant's innate immune system to allow infection, they may nevertheless be detected by surveillance systems in the plant. The constant evolution of pathogen effectors and host resistance proteins to, respectively, evade or gain molecular recognition, provides an intense

Figure 5 Recognition of AVR3a EM and KI in CPC accession *S. chacoense.*

arms race that may be exploited to seek durable forms of resistance for future potato breeding efforts. We have adopted a strategy to find effectors that are relatively conserved at the sequence level in pathogen populations; that are expressed in all pathogen isolates; and that provide an essential virulence function. Such effectors provide a point of vulnerability, an Achilles' heel, for the pathogen *if* resistance proteins can be found that detect and respond to them. To find such resistances, we are screening the Commonwealth Potato Collection for wild *Solanum* genotypes that respond to expression of these key effectors. A number of promising resistances have already been found in this way (Fig. 5), and their judicious combination in finished cultivars provides the potential for durable resistance to defeat our major crop diseases, and to reduce the levels of chemicals currently needed to control them.

Fooling the bugs – using plant volatiles as chemo-attractants in integrated pest management schemes

Tom Shepherd & A. Nick E. Birch

In northern and central Europe, raspberry production can be seriously affected by two major pests: raspberry beetle, *Byturus tomentosus* and raspberry cane midge, *Resseliella theobaldi.* The beetles lay eggs on opening buds and flower heads, and the resultant larvae burrow deeply into the berries to feed on the plug. This can result in damage to flowers and fruit with subsequent crop rejection. Splits in young canes caused by damage or natural splitting are the sites of egg laying by adult female raspberry midges. Emerging larvae feed on the pith, causing lesions which provide a means of entry for diseases such as cane blight fungus and midge blight. Currently there is an urgent need to reduce pesticide usage under revisions to EU pesticide policy 91/414/EEC, therefore development of environmentally friendly control measures forming part of an Integrated Pest Management (IPM) system are becoming vital. Two aspects of a successful IPM approach may include monitoring of insect numbers to improve the timing of insecticide treatments and use of control measures to

Figure 6 Bucket trap for monitoring raspberry beetles. The trap mimics the exact colour and scent of a raspberry flower.

disrupt the normal life cycle. Methods for monitoring and biological control of pests involve development of monitoring and mass trapping systems using natural chemical attractants as lures ('biomimicry' of the host plant). In the case of raspberry beetle, analysis of floral volatiles at SCRI using gas chromatography-mass spectrometry (GC-MS) in conjunction with electrophysiology, resulted in identification of several beetle attractants which now serve as a lure used in a

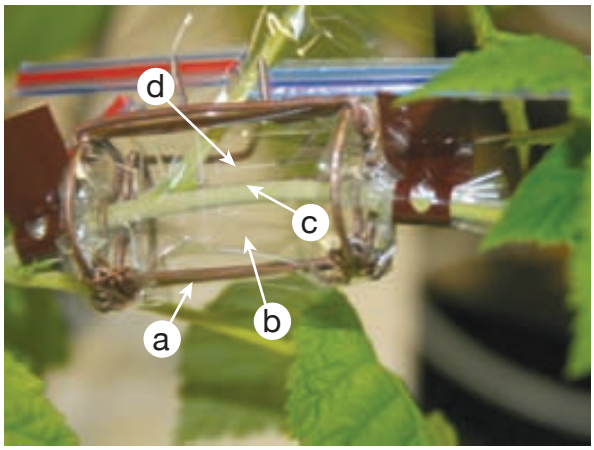
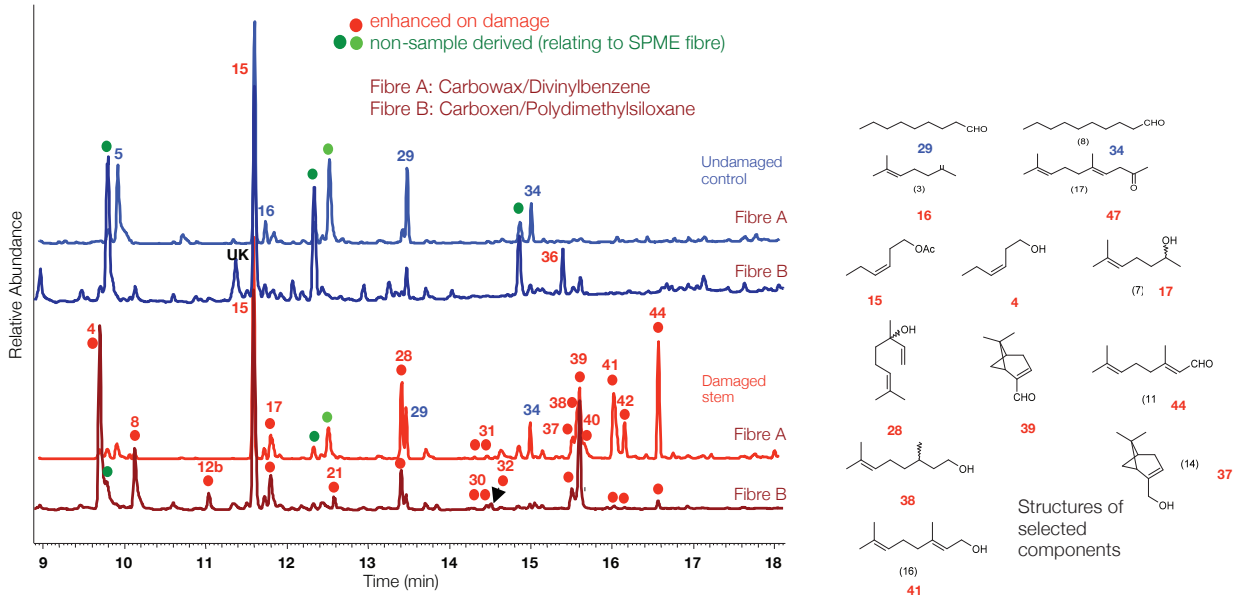


Figure 7 Enclosure for sampling volatile chemicals released from raspberry stems.
Wire frames (a) supporting an inert plastic film (b) were positioned around the cane at sites having a 2–3 cm manually created split (c). SPME fibres (d) inserted into the enclosure adjacent to the split trap released volatiles which were then desorbed in the GC injector and analysed by GC-MS.



4: *cis*-3-hexen-1-ol; 5: camphene; 8: 2-heptanol; 12b: unknown terpene; 15: *cis*-3-hexen-1-ol acetate; 16: 6-methyl-5-hepten-2-one; 17: 6-methyl-5-hepten-2-ol; 21: 5-ethyl-2(5H)-furanone or 5-methyl-4-hexen-3-one; 28: linalool; 29: *n*-nonanal; 30: citronellal; 31: *trans*-pinocarveol or *trans*-verbenol; 32: unknown; 34: *n*-decanal; 36: methylsalicylate; 37: myrtenol; 38: β-citronellol; 39: myrtenal; 40: nerol; 41: geraniol; 42: neral; 44: geranial

Figure 8 Volatile metabolites released from stems of raspberry cv Malling Promise analysed using SPME and GC-MS.

device (Fig. 6) marketed by AgriSense Ltd for precision monitoring of this key pest, so 'hot spots' can be treated as required.

For monitoring and control of raspberry midge two approaches are being taken. Traps developed and tested by colleagues at the Natural Resources Institute (NRI) and East Malling Research (EMR) use the female sex pheromone for local monitoring of males and, potentially, also for mating disruption. However, effective control requires identification of an attractant to lure emerging females in early spring (first generation) and during the second generation, coincident with fruit harvest and the main period of fungal colonisation. We have developed a novel sampling technique using solid phase microextraction (SPME) fibres to trap cane volatiles close to a split (Fig. 7).

A suite of volatiles has been identified, using several different raspberry varieties, which show a consistent pattern of enhancement following damage (Fig. 8). These compounds consist mainly of a family of structurally related terpenes, many of which are known to have behavioural effects on insects and plants (for example they attract natural enemies) and/or are produced in response to insect herbivory.

The physiological activity of the entrained volatiles is being investigated with collaborators at NRI by means of a GC-electroantennography (EAG) system which identifies the metabolites that elicit a response from the antenna of female midges. Compounds showing enhanced production when canes are damaged, and those shown to elicit a response from the midge are being used to test and develop lures for biological control and monitoring using laboratory and field based behavioural bioassays developed by SCRI, EMR and NRI. This work is funded by a five-year HortLINK project (SF 74): 'Integrated pest and disease management for high quality raspberry production'.

Water use efficiency in potato

Ankush Prashar, Timothy S. George, Gavin Ramsay, Paul D. Hallett, Hamlyn G. Jones*, Peter Hedley, Jim W. McNicol, M. Finlay B. Dale, Philip J. White & Glenn J. Bryan

Water is one of the key resources challenging the sustainability of modern agriculture. In developing countries, potato production is increasing because of its ability to provide nutritious food in a short season. However, the potato crop requires profuse irrigation. In the UK, potato production currently uses about half of

*University of Dundee

Figure 9 Phenotypic screening of extreme $\delta^{13}C$ genotypes under controlled conditions.

all irrigation water. Further climate change is inevitable and, as this proceeds, summers are predicted to become drier and water for irrigation scarcer.

Yields of commercial potato varieties are often restricted by water availability. Their root systems are generally sparse and shallow, and they close their stomata, preventing photosynthetic carbon assimilation, while water is still available in the soil. To enable breeding of drought tolerant varieties, we are developing phenotypic screens that will allow us to explore the genetic basis of key traits for water use efficiency (WUE).

From field trials of a genetic mapping population performed in collaboration with Dr Andrew Thompson of Warwick-HRI, we initially identified ten genotypes with contrasting transpiration efficiencies based on leaf $\delta^{13}C$ values. These genotypes were then cultivated under controlled glasshouse conditions in a soil typical of arable fields in Scotland (Fig. 9). After emergence, plants were grown for 30 days in soils watered to field capacity (30% volumetric content, -5 kPa water potential) before being divided into three groups irrigated to 30%, 20% (-300kPa, slight stress) and 12% (-1500kPa, wilting point) volumetric content. As WUE is a complex phenomenon, we evaluated a number of associated physiological and morphological traits. Tissue samples were also collected at different time points to determine differentially expressed genes at these moisture levels.

Response to water stress not only includes closing stomata but also reducing the density of stomata during leaf development. Preliminary data from our experiments shows that transpiration-efficient genotypes, as indicated by low leaf $\delta^{13}C$ values, have consistently lower stomatal conductance at 12% volumetric soil moisture than transpiration-inefficient genotypes (Fig. 10). Thus transpiration-inefficient genotypes transpire more water at lower soil water content.

Another approach we are taking to improve the drought tolerance of potatoes is to screen genotypes for root length, specifically that associated with stolons. A

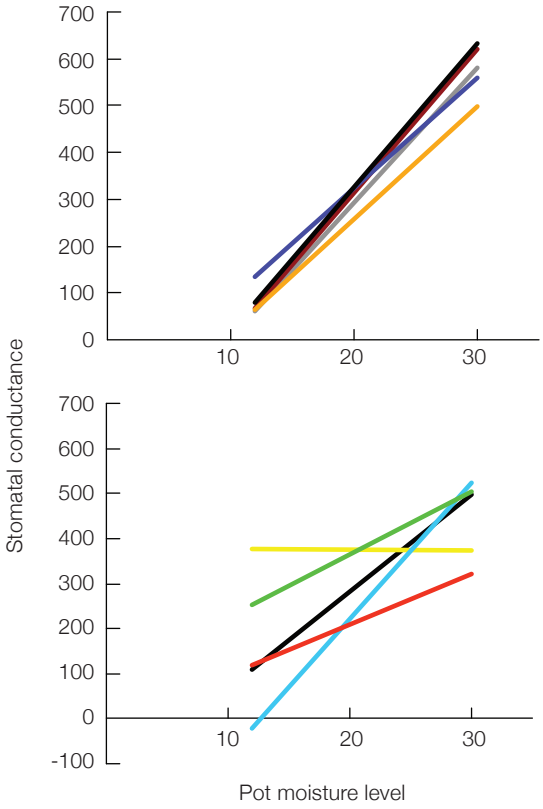


Figure 10 Regression of stomatal conductance against pot moisture levels for the five selected clones with low and high $\delta^{13}C$ values from a prior field experiment.

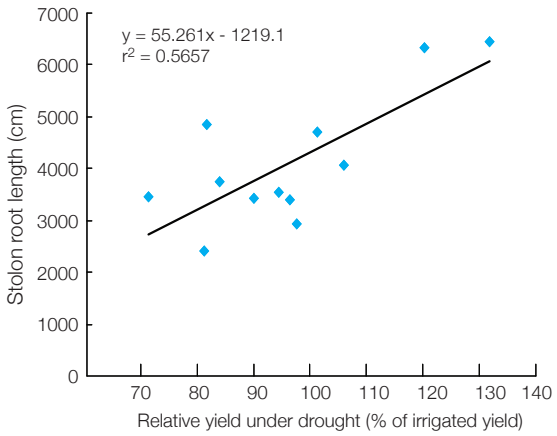


Figure 11 Relationship between stolon root length and relative yield under drought conditions in the field experiment.

number of field trials have demonstrated that there is significant variation (~5-fold) in stolon root length between genotypes of potatoes. During last year's field season we demonstrated that stolon root length

Figure 12 a) Potatoes grown under polytunnels to impose droughted treatments in 2009. b) Measurement of soil water content down the profile to establish the impact of the drought and irrigation treatment of soil water availability.

was strongly correlated with the ability of the potato plants to yield under droughted conditions (Fig. 11). This was achieved by growing potato cultivars with extreme rooting phenotypes under polytunnels with and without irrigation which developed strongly contrasting water availabilities in the field (Fig. 12). It is therefore apparent that as well as transpiration efficiency, rooting characteristics are likely to be critical for drought tolerance in potatoes.

These phenotypic screens in combination with microarray analysis will help us understand the basis of WUE and enable us to correlate WUE with gene expression in appropriate tissues. Identification and mapping of candidate genes that underlie WUE will ultimately enhance breeding for water efficient varieties in multiple environments.

SCRI's Balruddery Farm

A new platform for sustainability research at SCRI

Cathy Hawes & David W. Hopkins

The long-term viability of farming in Scotland depends on the sustainable management of our agricultural habitats. Intensification of arable systems to maximise crop yields in the short term has raised serious concerns about the functioning of arable systems and food security in the long term. The challenge now is to identify appropriate sustainable management practices and associated crop varieties that will allow farmers to achieve a balance between the potentially conflicting goals of maximising crop production, conserving arable biodiversity and maintaining ecosystem functions.

To do this, SCRI is establishing a new experimental research platform at Balruddery Farm near Dundee, for long-term studies on arable sustainability. The Centre for Sustainable Cropping – Balruddery is the first of its scale in the UK and will provide a test-bed for new management practices and 'sustainable' crop varieties developed at SCRI. The six fields that make up SCRI's Centre for Sustainable Cropping cover approximately

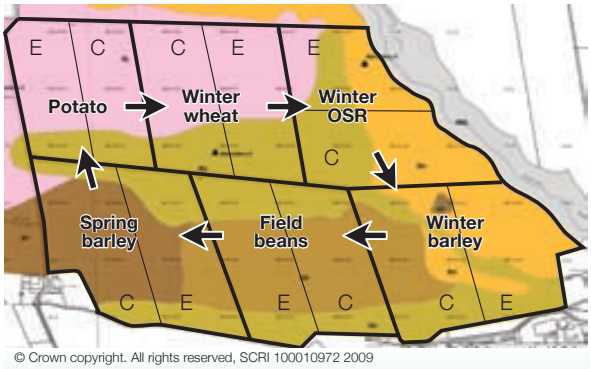


Figure 13 Layout of fields and treatment (conventional [C] and experimental [E]) management methods within the sustainability platform at Balruddery Farm.

40 ha in the south-east corner of Balruddery Farm. Each field will be divided into two halves according to topography, boundary vegetation and soil type. The conventional and experimental management treatments will be randomly allocated to each half field. Four to five different varieties of the six crops in the rotation will then be sown across both treatments, providing a comparison of varietal differences in performance (Fig. 13). Background on the farm and the design of the platform was given in the SCRI Annual Report for 2008 and further details can be found at www.scri.ac.uk/sustainability

The experiment will start with the sowing of winter wheat, barley and oilseed rape varieties in autumn 2010 and beans, barley and potatoes in spring 2011. Maize was sown in April 2009 to provide a C_4 input to the existing C_3 based system that will be used as a signal to trace carbon fluxes and turnover under the two contrasting management systems. The maize crop grew well during 2009 and was cut at cob formation in September when the crop was between 1.2 and 1.8m high (Fig. 14). The entire crop residue was chopped and incorporated in the autumn. A second crop will be grown and incorporated in the same way in 2010 to boost C_4 levels in the soil and extend the period over which the pulse can be detected during the first rotation. This signal will provide a tool to characterise the flux of carbon from plants to soils, the processing of these inputs through components of soil food webs and their return to the atmosphere through biological activity.

Figure 14 Maize at Balruddery grown to provide a C_4 signature for measuring carbon dynamics.

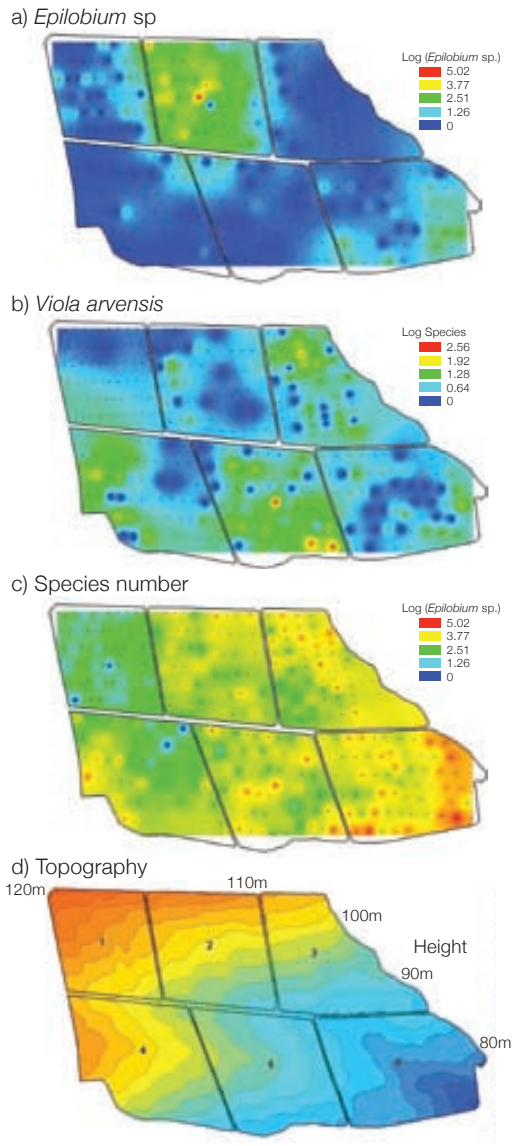


Figure 15 The distribution, abundance and diversity of arable weeds in the seedbank as assessed in spring 2009.

Baseline data is being collected on a wide range of system properties including arable plant and invertebrate biodiversity, soil microbial diversity and function, soil chemistry and biophysics, hydrology, nutrient and carbon fluxes and greenhouse gas emissions. The distribution, abundance and diversity of arable weeds in the seedbank was assessed in spring 2009 by identification of emerged weed seeds germinating from soil samples collected from a grid of 60 sample points across each field. The data shown include the weeds from the first flush of emergence only (Fig. 15). This is a good representation of the

arable seedbank diversity, but does not provide an estimate of absolute abundance. The full dataset will be reported in 2010. However, these data indicate a high degree of spatial variation across the site. *Epilobium* sp. (willowherb) is concentrated in one field (Fig. 15a), whereas *Viola arvensis* (field pansy) is more widely distributed (Fig. 15b). Species richness (Fig. 15c) is lowest in the north-west corner and increases towards the south-east, following the NW-SE slope across the Centre (Fig. 15d). Explanations for these patterns from field histories and erosion patterns will be sought and trends away from this baseline under conventional and experimental management will be measured annually. The data collected during 2009 and 2010 will provide the baseline against which to assess future changes in soil health, biodiversity and system functions under experimental and conventional field management.

A major obstacle to the adoption of more sustainable farming practices in Scotland is the short-term economic situation of farmers which provides a strong incentive for intensive crop production methods. Maximising yield is therefore often prioritised over management for environmental sustainability, particularly as the latter is generally ill-defined. The aim of the Centre is to quantify the longer-term costs and benefits of new 'sustainable' crop varieties and management practices at a scale that is relevant to commercial farmers. This will provide the data necessary to identify a balance between the risk of potential short-term loss for long-term environmental and economic gain.

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Communications – Review of the Year

Phil Taylor

SCRI enjoyed an astonishingly busy year from the perspective of the events and public engagements in which the staff participated.

It was also a watershed year in the Institute's history following the decisions of both the SCRI and Macaulay Land Use Research Institute's Governing Boards to accept in principle the formation of a new, research organisation.

The 'New Institute', as it has been tantalisingly christened, will combine the respective strengths of both institutes while at the same time exploiting new scientific opportunities and the advantages of scale.

Directors and senior scientists from SCRI and the Macaulay Land Use Research Institute at their first joint meeting in Montrose.

The Scottish Government's Cabinet Secretary for Rural Affairs and Environment, Richard Lochhead MSP, summed up the aspirations of all concerned when he said: "Both SCRI and the Macaulay already enjoy well-deserved reputations for excellence. Together they will be in an even stronger position to compete in the international arena and to address complex global issues, further raising Scotland's profile on the world stage."

It may be the case that SCRI's 2009 Annual Report is the penultimate edition. Happily there is no shortage of events, visits and achievements to fill the pages.

2009 was the first year in which several of SCRI's major stakeholder knowledge exchange events were held at Balruddery Farm. Balruddery was purchased by SCRI in 2008 and comprises 118 hectares of arable farm land located seven miles west of Dundee and between 70 and 160 m above sea level on the lower slopes of the Sidlaw Hills.

Cereals in Practice which saw an encouraging growth in attendance in its first year at Balruddery.

Both Cereals in Practice and Potatoes in Practice were transferred to Balruddery and both events were hailed as successes.

Cereals in Practice (CiP) is organised jointly by SCRI, SAC (Scottish Agricultural College) and SSCR (Scottish Society for Crop Research). It is also supported by HGCA (Home-Grown Cereals Authority). It is the key event in the cereals industry calendar in Scotland.

More than 200 visitors arrived on the day, more than twice the number of visitors than in previous years and including a large group from Sweden.

Dr Keith Dawson, SAC's Principal Crops Consultant, who is also chairman of the SSCR Combinable and Energy Crops Sub-committee, said: "There was a tremendous amount of work done by all concerned to bring together the programme for the event.

"The whole aim of the work we do is to try to speed up the development of knowledge from the research lab through to the field and through on to the farm to benefit the consumer and the industry as a whole."

In August, Potatoes in Practice (PiP), the UK's largest potato industry field event, also made the move to Balruddery Farm. For the second year running, very heavy rain immediately before the event caused some difficulties. Happily a bright and windy day soon helped dry the ground. More than 600 visitors made the journey to this lovely corner of Angus. The biggest proportion was farmers, closely followed by those active in marketing and retail.

PiP was sent a message of support from Roseanna Cunningham MSP, Scotland's Environment Minister. She said: "Potatoes in Practice is a great example of Government and industry working in partnership to create a real Scottish success story. Participation in events such as this helps to ensure that Scotland will retain – and expand upon – its leading position." Later in the year SCRI and Mylnefield Research Services Ltd (MRS Ltd) joined forces at British Potato, the Potato Council's biennial show at Harrogate in Yorkshire.

Fruit for the Future, SCRI's knowledge exchange event tailored for the soft fruit sector, also saw some changes in 2009. It too has seen a steady growth in audience numbers and it was necessary to relocate from the

Commonwealth Potato Collection Assistant Curator, Gaynor McKenzie, with a special CPC display at Potatoes in Practice.

Guests at the 2009 Fruit for the Future event – the biggest to date.

Institute's biggest lecture theatre to a larger marquee set up on the lawns in front of the headquarters.

Guests on a tour of the polytunnels at the 2009 SCRI Director's Summer Soirée.

The installation of the marquee gave us the opportunity to host a summer evening soirée on the same evening on behalf of SCRI's Director, attended by more than 100 friends and stakeholders of SCRI.

Each year the Scottish Research Institutes host a distinguished lecture under the title Science for Life. This year it was the turn of SCRI to host the event and the invitation to speak was kindly accepted by Professor Emeritus Thomas Rosswall.

Swedish born Professor Rosswall, recently retired Executive Director of the International Council for Science (ICSU), speaks on behalf of the Challenge Programme of the Consultative Group on International Agricultural Research. This is a consortium of more than 2000 scientists in 100 countries with over $500 million invested each year for research for development.

He told his audience at Dundee's science centre, Sensation, that the issues of food security and climate change had to be much more closely linked.

The central message of his lecture was that the global demand for food is expected to increase by 50% by 2030 as the population grows and consumption patterns change. He said there was an urgent need to connect climate change and food security both in scientific and policy contexts.

The Science for Life lecture is also the opportunity to run a postgraduate student competition testing oral and presentation skills. Happily for SCRI, the 2009 winner was our own Lindsay McMenemy, a member of the Environment Plant Interactions programme. Lindsay's presentation topic was: 'Plant mediated interactions with the large raspberry aphid.' Professor Rosswall made the prize presentation of a certificate and cheque.

Lindsay McMenemy, winner of the 2009 Scottish Research Institutes' Student PhD competition (middle) with her fellow contestants, Peter Gregory and guest speaker Professor Thomas Rosswall.

The runners up were: Paula Scott from the Rowett Institute of Nutrition and Health and Kerry Waylen from the Macaulay Land Use Research Institute.

Another award went to Susan McCallum of SCRI who won the Innovation prize, which is supported by the Mylnefield Trust and MRS Ltd. Susan's title was: 'Marker assisted breeding for sensory characteristics in red raspberry (*Rubus ideaus* L.)'.

For Lindsay McMenemy it was the second achievement of the year: she was awarded the runner-up prize in a student essay competition run by the Royal Entomological Society.

Another notable achievement was the award to SCRI's Dr Julie Graham of the Royal Horticultural Society's Jones-Bateman Cup. The trophy is awarded by the RHS every three years to recognise major advances and excellence in fruit research. It is the second time in recent years that SCRI has been recognised. A previous winner was Dr Rex Brennan for his work on blackcurrants.

Dr Graham's research focuses on identifying genetic markers for desirable traits in raspberries such as taste and pest and disease resistance. Her research has led to new more specific and timely breeding methods which are based on an understanding of the link between genotype, the genetics of the plant, and the phenotype, what the plant looks or tastes like.

Dr Julie Graham, winner of the RHS Jones-Bateman Trophy.

Four SCRI scientists won an outstanding paper award from the American Journal of Potato Research. (Morris, W.L., Ducreux, L.J.M., Bryan, G.J. and Taylor, M.A. 2008. Molecular dissection of sensory traits in the potato tuber. *American Journal of Potato Research* **85,** 286-297.) Mark Taylor, Laurence Ducreux and Wayne Morris are members of the Plant Products and Food Quality

programme and their colleague, Glenn Bryan, works with Genetics. Their former colleague Walter de Jong collected the award on the authors' behalf at the Potato Association of America annual meeting in August in New Brunswick, Canada.

An 'outstanding paper' award from the American Journal of Potato Research was received by (left to right) Laurence Ducreux, Wayne Morris, Glen Bryan and Mark Taylor.

Later in the year SCRI and the University of Dundee's College of Life Sciences hosted the annual Distinguished Lecturer Seminar. It was delivered by Professor Nick Harberd who was at the John Innes Centre for many years before moving to the University of Oxford to take up the Sibthorpian Professorship in Plant Sciences.

The busy season of SCRI events continued with a new, joint venture involving the Royal Botanic Garden Edinburgh. The 'Berry Festival' was held over a weekend in July and visitors to the Garden's exhibition centre were treated to the story of Scotland's rich and diverse berries.

Photographs, living plants and other exhibits celebrated the bewildering variety of raspberries, strawberries, blackcurrants, brambles, tayberries and other fruits and demonstrated the science behind Scotland's berry industry.

SCRI was also the driving force behind the biggest event in the 2009 calendar of activities organised by KnowledgeScotland. This is a knowledge exchange initiative funded by the Scottish Government and run jointly by all the Scottish Research Institutes.

'Science Policy Success' was a two day conference held at Dynamic Earth in the early autumn. One hundred and thirteen delegates watched presentations on the themes of health and wellbeing, climate change, biodiversity and sustainability. There was also an acclaimed presentation by the writer and broadcaster Lesley Riddoch who discussed the task of communicating complex information to the public.

Scottish Government Chief Scientist, Dr Anne Glover, addressing the Science Policy Success conference at Dynamic Earth in Edinburgh.

The post-conference evaluation found that 71% of those responding believed that the conference had achieved its aim of improving links between science and policy.

In September, scientists from all over the world travelled to Dundee for the meeting of the 'Biometrics in Plant Breeding' section of EUCARPIA, hosted by SCRI. More than 100 delegates took part and also enjoyed a

Professor Mike Kearsey of the University of Birmingham speaking at the EUCARPIA conference dinner where he was honoured for his long and distinguished career.

Delegates at the EUCARPIA conference at their civic reception in Dundee.

civic reception hosted by the Lord Provost of Dundee, Councillor John Letford. Later they had a memorable dinner on board HM Frigate Unicorn, one of the last intact warships from the days of sail, and one of the six oldest ships in the world.

Towards the end of the year, a stakeholder day was organised on behalf of the Scottish Government's research initiative Programme 1: Profitable and Sustainable Agriculture – Plants. The day included short presentations from scientists contributing to RERAD's commissioned research and from relevant policy divisions.

Three other set-piece events helped to put SCRI in touch with its audiences.

The 2009 Royal Highland Show set a new attendance record over its four days with 176,522 people coming through the gates at the Royal Highland Centre, Ingliston, Edinburgh.

At the SAC Pavilion SCRI presented the 'timeline' of the Institute's history and also an interactive display of the Living Field run by staff from Environment Plant Interactions. In the Royal Highland Education Trust

Her Majesty The Queen at the Royal Highland Show, Ingliston. The Queen spent nearly 10 minutes chatting to staff and Dundee school visitors at the SCRI stand in the Royal Highland Education Trust building.

building, a team from Communications introduced a younger audience to the work being done on berries, nutrition and health. The highlight for the team was a visit from Her Majesty the Queen who spent nearly 10 minutes chatting to staff and a party of visiting schoolchildren from Dundee.

For the second year running, SCRI joined the staff of Edward Baxter's Gilston Mains Farm in Fife for LEAF (Linking Environment and Farming) Open Farm Sunday. Once again the Living Field team was in action.

Celebrity guest Stephen Purdon from the BBC's River City soap with visitors to LEAF Open Farm Sunday.

The Institute's work on soft fruit was the centrepiece of the display mounted for the Dundee Flower and Food Festival in early September.

SCRI hosted a number of special guests during 2009 and they included members of parliaments far and

SAC Chairman, Lord Jamie Lindsay with the SCRI Director during a visit in July.

Members of the European Parliament on a visit to SCRI.

wide. Pete Wishart MP (Perth and North Perthshire) is a long time supporter of SCRI and was welcomed back to Invergowrie in September. Another very supportive politician, Alyn Smith MEP, was also welcomed back to SCRI during the year. In August the Director welcomed a visitor from further afield: Tony Windsor MP – a member of the Australian House of Representatives for New England.

On the day of Fruit for the Future SCRI hosted Lord Jamie Lindsay, a former Scottish Agriculture Minister and currently the Chairman of SAC. He met the Director and then was hosted by all the science programmes before being taken on a quick tour of the glasshouses, the Commonwealth Potato Collection and the Living Field.

SCRI's strong links with the Scottish Government were reflected in visits from Ron Stagg, Deputy Director, Research and Science Division, Scottish Government – Rural and Environment Research and Analysis Directorate and from Dennis Dick, a former Chairman of the Scottish Wildlife Trust and a member of the Scottish Biodiversity Committee which is advising the Government on the 2010 UN Year of Biodiversity.

One of the most memorable seminars to be held at SCRI during the year featured the renowned Professor Dianne Edwards, Head of the School of Earth, Ocean and Planetary Sciences at Cardiff University. Professor Edwards is also a fellow of the Royal Society and a trustee of the Natural History Museum and the National Botanical Garden of Wales.

Her lecture was one of the many events to celebrate the achievements of Women in Science, Technology, Engineering and Mathematics (STEM) that took place at

Eleanor Gilroy demonstrates 'You choose the news' - an interactive game on the theme of GM.

the Universities of Dundee, Abertay and St Andrews and at SCRI and the Sensation science centre.

SCRI's strong links with organisations furth of Scotland were underlined by involvement in a major Biotechnology and Biological Sciences Research Council (BBSRC) project and an award from the Monsanto Trust for a project in Africa.

SCRI and the University of Dundee are collaborating in a £27 million Sustainable Bioenergy Centre under the auspices of the BBSRC.

The centre was launched to provide the science to underpin and develop the important and emerging UK sustainable bioenergy sector. It represents the biggest ever single UK public investment in the field.

The University of Dundee, based at SCRI, was named as one of the six research hubs of academic and industrial partners to benefit from the investment. The Dundee-led team (which includes SCRI) aims to alter lignin production in barley to make it easier to produce bioenergy from waste straw without reducing the quality of the crop.

In another project SCRI is leading an international project to help potato farmers in Kenya. The mission is being supported with a grant from the Monsanto Fund totalling £186,000.

The ambition is to increase potato yields – and importantly farmers' incomes – by establishing systems

Dr Lesley Torrance of Plant Pathology with the Monsanto Fund's Bridget Badiou at the launch of an international project to help potato farmers in Kenya.

to support virus-free potato seed tuber production. The potato is the second most important food crop in Kenya after maize; 1.2 million tonnes are grown every year.

SCRI's Head of Plant Pathology, Dr Lesley Torrance is leading the project. She said: "There is massive scope for crop improvement by effective control of virus diseases and their aphid carriers. We hope to increase potato yields and thereby farmers' incomes on a sustainable basis."

Farewell to John: Dr John Bradshaw is presented with a leaving gift on his retiral after a distinguished career at SCRI.

During 2009 the Institute bade farewell to several long-serving and distinguished members of staff. Dr John Bradshaw, one of the world's leading plant breeders, retired at the end of March. John began his career in Scotland at the Scottish Plant Breeding Station in Pentlandfield, Edinburgh 33 years ago. Latterly at SCRI he led the Potato Genetics research programme.

SCRI Director, Professor Peter Gregory, said John embodied what was best about SCRI. "John is an academic to his fingertips and has a love of his subject. He has the ability to communicate the passion that he has for his subject. But he's not just an academic who operates on his own. He interacts with many other people within the Institute. He conveys that passion to visitors and in scientific meetings and in particular he has converted that academic passion into commercially useful products that people want to buy. It is a marvellous testimony to his whole career that he has been able to do these things bringing great credit to both him and to the institute."

SCRI also said farewell to Mike De,Maine, who retired from SCRI at the end of April after long and distinguished service, latterly as the Health and Safety Manager.

Mike De,Maine's retirement.

Ronnie Forbes RSA takes a breather during the launch party for his SCRI portfolio.

Two members of staff celebrated 40 years service with SCRI: Alex Mills, a soft fruit specialist with Field Services, has planted and tended tens of thousands of raspberry canes and blackcurrant bushes. Ronnie Ogg, another member of the Invergowrie community, has also spent 40 years working in the glasshouses and has been a stalwart helper at all the Institute's public events.

Much of SCRI's work in genetics, plant pathology, environment plant interactions and food has now been summed up in stunning imagery by the Leverhulme Trust artist-in-residence, Ronnie Forbes RSA. Ronnie's time with SCRI came to an end, but his portfolio of work went on public show during the year, starting at the Hannah Maclure Centre in Dundee. The body of work produced during his residency – De Rerum Natura: The Nature of Things – forms a narrative around the way we see and understand the world. The work comprises large paintings, unique digital-collage prints and a film. More exhibitions of his SCRI work are planned in the year ahead.

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Biomathematics and Statistics Scotland

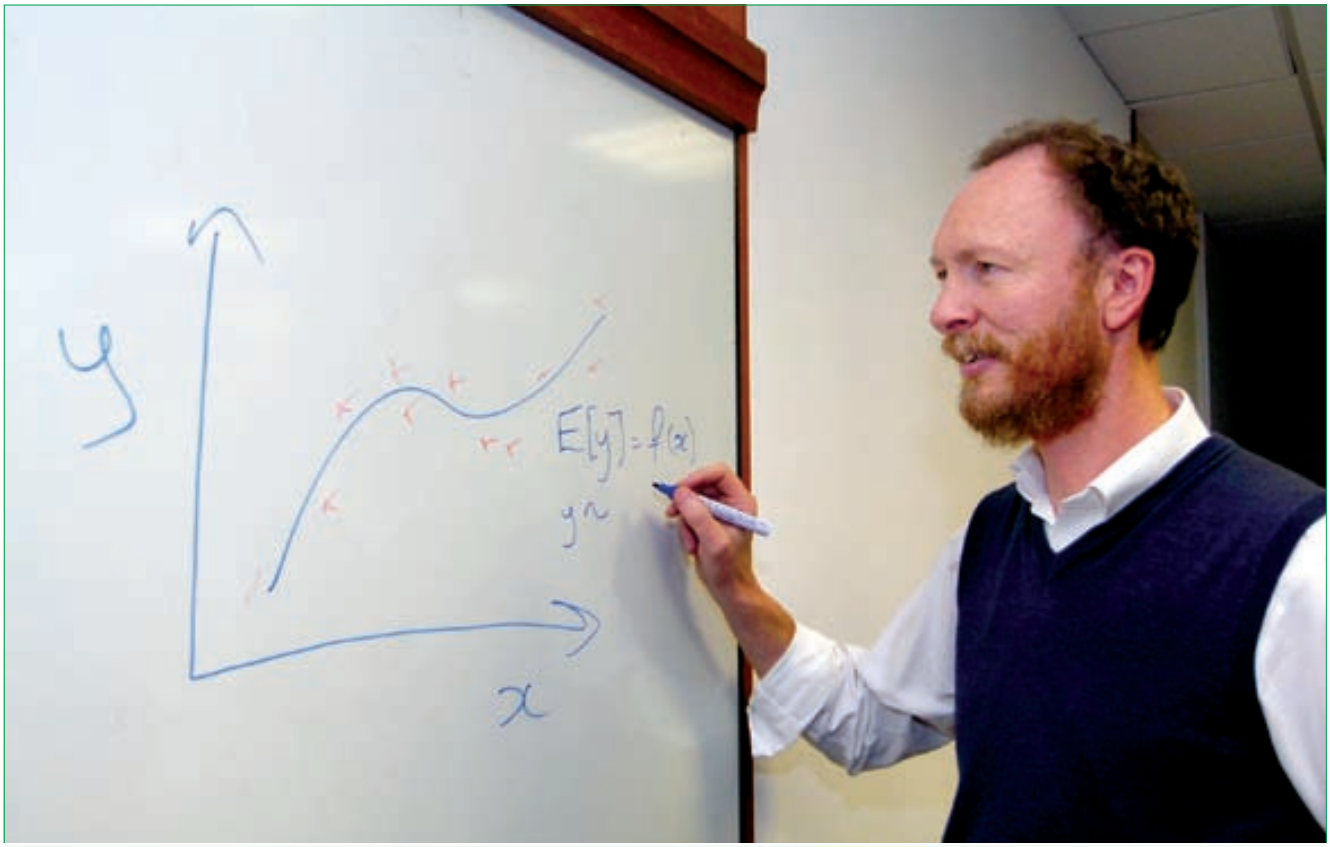
David A. Elston

Biomathematics & Statistics Scotland (BioSS; www.bioss.ac.uk) delivers research, consultancy and training in statistics, mathematical modelling and bioinformatics. Although BioSS forms part of the SCRI Group, its work is equally relevant to a number of other scientific organisations. Indeed BioSS plays a unique role in the Scottish research community. It bridges the gap between research in the mathematically based and traditionally more qualitative sciences. BioSS staff work within four broad application areas: plant science; animal health and welfare; ecology & environmental science; and human health & nutrition. Our programme of applied strategic research addresses generic issues encountered in these application areas and is managed in three broad themes: statistical bioinformatics; systems & process modelling; and statistical methodology.

Improving Quantitative Trait Locus (QTL) analysis for key crop traits

Chris A. Hackett

During 2009 BioSS marked up 20 years of collaboration with SCRI scientists in the area of linkage analysis and QTL mapping. The central idea of estimating genetic distances between DNA markers on the basis of recombination between them, and relating variation at marker positions to variation in phenotypic traits to locate genetic regions affecting these traits, remains unchanged. However we have seen major changes in the types of population, the markers, the traits of interest and the statistical approaches needed. In this review we look back over this progression, and forward to new developments.



David Elston, Director of BioSS.

The first collaboration was an analysis of an F_2 barley population, relating height and ear emergence to two markers on chromosome 4. This required the development of a novel mixture model with two unlinked genes interacting epistatically to control the vernalisation requirement. Subsequent collaborations have involved many more markers, as different techniques have developed: Restriction Fragment Length Polymorphisms (RFLPs); Random Amplified Polymorphic DNA (RAPD); Amplified Fragment Length Polymorphisms (AFLPs); Simple Sequence Repeats (SSRs). Single Nucleotide Polymorphism (SNP) analysis and Diversity Arrays Technology (DArT) now enable linkage maps of barley to be constructed with more than 1000 markers.

Barley is an ideal crop for QTL analysis, as studies on barley typically begin with homozygous parents, where recombination can be estimated with few complications. However research at SCRI has expanded to include QTL studies for all the major crops here. In raspberries and blackcurrants, mapping populations are usually derived by crossing two (outbreeding) parents and studying their F_1 progeny. Potato has the further complication that the breeders' potato is autotetraploid. BioSS and SCRI obtained funding to develop the theory for mapping in autotetraploid species, and our methods have been incorporated in the software TetraploidMap for Windows. This has been used by other groups to develop linkage maps and locate QTLs in plants such as alfalfa, leek, coffee and rose and will be developed further to meet the needs of a new SCRI project on blueberry.

The phenotypic traits under investigation have also changed in number and type. The first collaboration involved two highly heritable characters. Subsequent studies have looked at yield, and yield components, which are less heritable. More recent traits have involved more complex analysis in advance of the QTL mapping and have required the expertise of BioSS in other areas: for example the analysis of sensory data from a tasting panel assessing different potatoes, and the analysis of colour data using image analysis techniques. A variety of statistical approaches can be

used to look at modelling developmental processes: principal coordinates were used to summarise a series of repeated visual assessments of raspberry ripening, and analysed to identify QTLs affecting different stages of ripening. Another role of the preliminary analysis is to check for spatial trends across field trials, or temporal trends related to the ordering of samples through laboratory testing, which can conceal or bias QTL effects.

Mixed models are being increasingly used in QTL analyses. Their flexible correlation structure means that they can be used to represent the relationship between, say, yields measured in different locations or under different treatment regimes in a factorial experiment, so enabling tests for QTL by environment interactions. These interactions can, in turn, be modelled in a mixed model framework as functions of environmental variables such as temperature or rainfall. Mixed models can also be used to combine trait values from related populations, taking into account the degree of relatedness: the scale of this can range from combining two or three large mapping populations that share a common parent through to association mapping of germplasm collections.

In the future, the challenges are most likely to come from the increasing dimensions of phenotypic data as ‘omics technologies lead to measurements of metabolites or gene expressions, or image analysis methods such as LemnaTec give detailed pictures of crop development. Dealing with these large, potentially multivariate data sets will be challenging both statistically and computationally. We anticipate further developments in the types and quantities of marker data, and changes in the target traits as issues of sustainability and food security in a changing climate become increasingly important.

Mylnefield Research Services Ltd

Nigel W. Kerby & Jonathan B. Snape

Mylnefield Research Services (MRS) Ltd, the wholly-owned commercial subsidiary of SCRI, celebrated its twentieth anniversary in 2009. It was established in 1989 by Professor John Hillman, the then Director of SCRI, to enhance competitiveness, understand and fulfil the needs of industry and maximise the value of SCRI intellectual assets and resources. Agricultural food production has changed radically over this period and the underpinning research has seen significant advances. The need for SCRI to be able to convert its excellent science into commercial products and services that meet industrial and societal needs, while stimulating economic development, has never been more acute. MRS has consistently generated profits that are reinvested in SCRI. The formation of a new research institute comprising SCRI and the Macaulay Land Use Research Institute in 2011 will ensure we are well positioned to meet the global challenges of food and energy security and climate change.

The twentieth anniversary of MRS was celebrated at the Director's summer soirée on the lawn at SCRI in August when local dignitaries, key stakeholders, past and present employees and directors enjoyed an evening of fine food (including potatoes and fruit bred by MRS and its partners) and entertainment.

Dr Nigel Kerby with Mr Murray Thomson and Mr Peter Berry.

MRS uses a diverse range of routes to commercialise SCRI expertise and intellectual property (IP), including: Spin out companies, for example EnPrint Ltd.; Joint Ventures, for example Danasia Berry (Beijing) Corporation; collaborative research projects for example long-term breeding contracts with GlaxoSmithKline and Greenvale AP Plc; licensing, for example we have granted 473 licences to plant varieties bred at SCRI; sale of products, for example barley molecular markers, plant virus antibodies; analytical services for example stable isotope analysis, lipid analysis; field and glasshouse services, for example supply of high-health plants, trialling new agrochemicals; consultancy, for example statistical services from BioSS.

Finances

The turnover of MRS was £1.9 million in 2008/2009.

MRS transferred £0.9 million to the SCRI Group, including £225k of Gift Aid. As in previous years, contract research (45%) was the biggest contributor to income, followed by royalties (26%) and analytical services (20%). In addition, MRS retained £91k (after tax) to increase significantly company reserves for future investments,

Knowledge transfer and exploitation

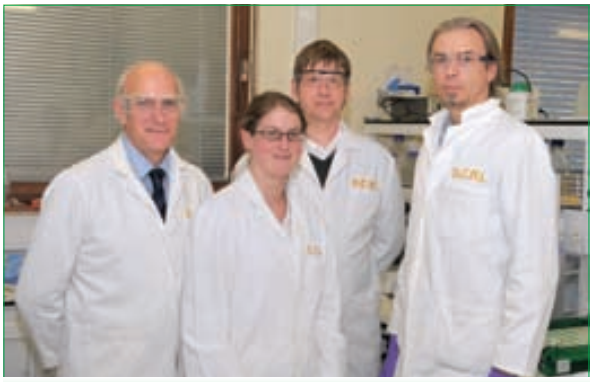
In March 2009, Dr Richard Gregson joined the MRS team. Richard, a trained patent examiner with a PhD in chemistry, is employed by Genecom and seconded to MRS with the sole aim of generating income from the commercialisation of SCRI's IP and resources. Genecom also provide funds to develop commercial ideas and in 2009, a project led by Dr Wolfram Meier-Augenstein was approved to develop methodologies to determine the authenticity of Scotch whisky using stable isotopes.

Analytical services

The early part of 2009 saw difficult trading conditions for Mylnefield Lipid Analysis. The impact of the financial crisis and the resultant recession saw a reduction in plantings of oil seed crops for use in health foods and nutriceuticals, and a major customer in the pharmaceutical sector closed its UK office and terminated its contracts with MRS. The second half of the year saw business pick up again, and following investment in a new TLC machine that attracted new customers, October 2009 was the most successful month to date for the business.

In addition, MRS was audited by the Medical and Healthcare products Regulatory Authority (MHRA) and can now operate to Good Clinical Practice. MRS is now working towards obtaining Good Manufacturing Practice and Good Laboratory Practice accreditation and has retained the services of Marilyn Emery Consultants to assist in this process.

Under the leadership of Dr Wolfram Meier-Augenstein, the stable isotope analysis business has shown steady growth that has necessitated the investment in new equipment and extra technical assistance. This business has been branded as Mylnefield Isotope Signatures and new marketing material and a website (www.isotopesignatures.com) have been developed. It is anticipated that combining increased marketing effort with extra analytical capacity will increase sample throughput and lead to further growth in 2010.



The launch of the spin-out company EnPrint©. From left to right: Dr Keith Winton, Dr Rayne Longhurst, Dr Tim Daniell and Dr David M Roberts.

Associated businesses

EnPrint Ltd was established in April 2009 with a £150k investment from the Genomia Seed Fund. EnPrint are developing laboratory-based analytical services for analysing complex populations of microorganisms based on methods pioneered by Dr Tim Daniell and reduced to practice by Dr David Roberts. These techniques have attracted considerable interest from

environment agencies and water companies in the UK and elsewhere in Europe. The challenge in 2010 will be to convert this interest into commercial contracts and raise sufficient finance to enable the company to develop a sustainable range of services.

MRS has a 10% stake in a cooperative joint venture, Danasia Berry (Beijing) Corporation Limited. 2009 saw the production of 57 tonnes of fruit in the Hairau district of Beijing and the establishment of new plantations. In addition, there has been a change in emphasis from summer fruiting varieties to primocane and significant investments in the infrastructure of farms and juvenile plants. Trials of SCRI 'Glen' varieties were established in 2009 and experiments on overwintering cane to protect from severe frosts were initiated. It is early days for this venture but MRS and our Danish partners – Berrifine Corporation and the Industrialisation Fund for Developing Countries (IFU) – are determined to increase both the quality and quantity of products through selecting appropriate varieties, extension services, transferring new technologies (for example protected cropping and drip irrigation) and training.

Human Resources

MRS attained a Bronze Award for its Investors in People submission. This accolade is testament to the commitment and dedication of all MRS staff. Of course, there is always room for improvement and in 2010 we will be looking at new ways to improve.

Plant breeding

MRS's commitment to plant breeding was evidenced by the employment of two new PhD plant breeders. Vanessa Young (potatoes) and Hazel Bull (cereals) will be undergoing rigorous training over the next five years to ensure that MRS has access to plant breeders with the skills required to exploit fully the data generated by genomics. It is anticipated that in 2010 an additional PhD plant breeder focused on soft fruit will be recruited.

A new raspberry breeding consortium was established in 2009 that has guaranteed funding for raspberry breeding for at least the next five years. The consortium comprises the Scottish Government, the Horticultural Development Company and most of the major raspberry propagators, growers and marketing groups in the UK. For the first time this breeding programme will utilise molecular markers developed at SCRI by Dr Julie Graham and her team. It is hoped that these developments will lead to a new generation of raspberry varieties that build on the market leading 'Glen' series of raspberries.

Finlay Dale (right) with John Bradshaw.

Following the retirement of Dr John Bradshaw in April, Dr Finlay Dale was seconded to MRS for 50% of his time in recognition of his commitment to delivering eight potato breeding programmes. Two major potato breeding programmes with McCain Potato and Greenvale AP were renewed in 2009. The potato breeding team was strengthened by the appointment of Jane Robertson. Two blackcurrant breeding programmes (one fresh, one processing) were ably managed by Dr Rex Brennan and look poised to deliver exciting new varieties in the coming years.

Licensing and royalties

Royalty income in 2008/2009 was the highest ever at £498k driven mainly by income from the raspberry

Loch Tay

variety Glen Lyon in Spain and Glen Ample in the UK and elsewhere in Europe. Income from blackberries showed strong growth following the release of Loch Tay and income from potatoes showed a steady increase due to the popularity of the new 'Vales' varieties marketed by our long-standing partner Greenvale AP Plc.

In 2009, three new potato varieties (Inca Bella, Chincha and Tabitha) were admitted on to the National List and two new varieties were submitted for National List Trials. EU Plant Variety Rights were applied for in relation to three varieties of blackcurrants, one potato variety and two varieties of the catch crop *Solanum sisymbriifolium*. Following the success of the arrangement to collect royalties from Glen Lyon in Spain, in late 2009 MRS concluded an agreement with the Spanish company Eurosemillas to act as agent for MRS raspberries and blackberries in Spanish and Portuguese speaking countries around the world.

Contract research

Despite the recession, income from contract research managed to grow by 18%. This is despite one potato breeding company going into administration and several potential major collaborations being put on hold pending more favourable economic conditions. Although many SCRI scientists contributed to this impressive performance, special mention should be made of Dr Alison Lees (potato pathology), Dr Julie Graham (soft fruit genetics) and Dr Derek Stewart (food quality).

Acknowledgements

MRS gratefully acknowledges the support of all SCRI staff, for their significant contribution to the success of the company. MRS would also like to thank its customers and sponsors for their continued support. Finally, we would like to thank the non-executive Directors of MRS who contribute their valuable time without recompense.

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Division of Plant Sciences

University of Dundee

John W. S. Brown

The Division of Plant Sciences has been very successful in attracting external research grant funding of over £9 million over the last 18–24 months. The grants are mainly from the BBSRC but also include EU funding and a major grant from the Global Climate and Energy project (GCEP) and will run for between 3–5 years. Claire Halpin has been the major contributor with £5.5M for projects on lignin biosynthesis and recombination. One aspect of much of this funding is the collaboration with SCRI research groups reflecting the special partnership between the College of Life Sciences of the University of Dundee and SCRI.

A major highlight was the January launch of the BBSRC Sustainable Bioenergy Centre (BSBEC), a virtual Centre with six research hubs. The Dundee centre is headed by Claire Halpin and is a collaboration with Robbie Waugh and Derek Stewart at SCRI. BSBEC is supported by £28 million of BBSRC funding, has many links with industrial partners and is focused on complementary research areas relevant to sustainable bioenergy.

We are pleased to welcome a new Fellow of the Royal Society of Edinburgh, Edgar Huitema, who joined the Division in October. His area of research is the function of a new class of effector proteins, the crinklers, in the plant pathogen, *Phytophthora*. He is associated with the Plant Pathology programme of SCRI and his work will complement that of Paul Birch in advancing our understanding of effectors and the defence

mechanisms that they target for suppression. This year, Paul Birch's research group was one of the leading groups involved in obtaining the genome sequence of *Phytophthora infestans*, the major pathogen of potato (published earlier this year in *Nature*). We also say a sad goodbye to Lyn Jones, Professor of Plant Ecology, who retired at the end of September. Lyn will remain active as he follows ongoing interests and collaborations.

The grant income success has also meant a rapid increase in the size of the Division to over 45 people. A challenge has been to reinforce the identity of the Division while many of its Principal Investigators are situated in different parts of the SCRI campus – mainly to reflect their research areas and opportunities for interaction and collaboration. The recent refurbishment of a corridor which houses three of the Plant Sciences groups alongside SCRI colleagues, has allowed many of the newly recruited scientists and technicians to be accommodated. In addition, it has also created a central hub for the Division where Morven Pearson (the Divisional Secretary) and Sandie Gray (recently appointed as Lab Manager) are situated alongside John Brown and Claire Halpin (the Head and Deputy Head of Division).

The Masters level MRes teaching course in 'Crops for the Future' began this October with its first intake of four students from Scotland, Poland, Pakistan and India. The course is a joint venture between the College of Life Sciences/Division of Plant Sciences and SCRI and builds on the unique combination of expertise of both organisations. Our MRes is highly topical as issues of food security and sustainability continue to dominate scientific policy. It aims to give students a strong grounding in modern plant and crop biology including genetics, genomics and new approaches to breeding and crop improvement.

Other scientific highlights include Gordon Simpson's work on the function of FPA in flowering time control and the demonstration that it controls RNA 3' end formation which has led to a successful grant to look at wider aspects of mRNA 3' processing in regulating expression. John Brown's group has discovered mRNAs and aberrant mRNAs in the nucleolus raising the possibility of novel functions for the nuclear compartment in regulating plant gene expression. Andy Flavell has developed a PCR based technology for Next Generation Sequencing of hundreds of candidate gene alleles in hundreds of barley genotypes as a basis for identifying alleles responsible for traits important to the breeder. Finally, Steve Hubbard has developed a number of interactions with SCRI colleagues in the Environment Plant Interactions Programme in particular looking at the dynamics of the interaction between the potato aphid (*Macrosiphon euphorbiae)* and its parasitoids, endosymbionts and plant pathogens and the impact of secondary bacterial endosymbionts on fitness of the cabbage aphid (*Brevicoryne brassicae)* and its capacity to resist parasitism and to transmit viral pathogens.

Postgraduate studies at SCRI

Craig G. Simpson & Tracy A. Valentine

Postgraduate training at SCRI provides an environment that allows technical and intellectual competences to flourish and equips students with modern scientific skills suitable for a range of scientific careers. Training in research skills and techniques is an essential element in the development of a research student. Students have the opportunity to use the considerable knowledge, techniques and technologies available at SCRI and their associated universities. The outcome is a partnership that makes a substantial and original contribution to knowledge in the research areas at SCRI.

The Institute is involved in the training of around 60 students at present, with about half supported through the very successful and highly competitive joint studentship programme. This programme is funded jointly through SCRI and the student's university. It has led to the highest student population at SCRI to date. This highly motivated group enhances scientific life at SCRI and positively challenges SCRI staff through vibrant scientific questioning and by developing novel techniques. The rigorous and demanding nature of the studentship is monitored through a process that

Susan McCallum won the Innovation Prize at the 2009 Student Competition.

requires a written report and short presentation with a selected impartial scientific advisor every six months. These meetings challenge the student with a different point of view and provide a record of their scientific and academic progress. The meetings are complementary to the monitoring system at the University at which the postgraduate student is registered.

The students at SCRI have established a committee that holds meetings and offers a chance for students to discuss aspects of postgraduate life and concerns. Two students are also members of the Institute University Interactions Committee (UIC) that deals with all aspects of postgraduate research at SCRI. They provide a valuable link between students and the function of the UIC. Informative occasional presentations were given in 2009 by members of staff to give advice on topics and skills relevant to postgraduate research.

SCRI played host to this year's Postgraduate Student Competition as part of the Scottish Research Institutes' annual Science for Life lecture. The competition involved an incredibly high standard of talks, confidently presented and defended. This was very much a celebration of the work going on around the Scottish Research Institutes. SCRI was represented by Susan McCallum 'Marker assisted breeding for sensory characteristics in red raspberry (*Rubus idaeus* L.)' and Lindsay McMenemy 'Plant mediated interactions with the large raspberry aphid', our winners of the internal SCRI student competition. Lindsay went on to win the competition following on from her success as runner-up in the 2008 Student Essay Competition run by the Royal Entomological Society.

The moment SCRI's Lindsay McMenemy learned she was the winner of the 2009 Scottish Research Institutes' Student PhD competition.

This year we welcomed postgraduate students to the Master of Research (MRes) course titled 'Crops for the Future' for the first time. This is a joint venture initiated between the University of Dundee College of Life Sciences and SCRI. The course provides a framework for advanced study in practical and theoretical aspects of crop bioscience through lectures from SCRI and Dundee University staff and through practical demonstration of modern agricultural and plant science practices.

The Scottish Society for Crop Research

Bill Macfarlane Smith

The Society has a role in raising awareness of items of interest and concern to the agriculture, horticulture and forestry industries. This is partially achieved by funding the Annual SSCR Lecture immediately following the Annual General Meeting. This year's AGM was held on Wednesday 27 May and the Annual Lecture was given by Professor Annie Anderson of the Centre of Public Health and Nutrition Research, the Division of Therapeutics and Medicine at the University of Dundee Ninewells Hospital and Medical School. The title of the lecture was, 'The challenge of achieving a healthy and sustainable diet in Scotland'.

The Society currently supports research on a range of topics, including research into differential cultivar response to soil physical constraints in winter and spring barley, integrated pest and pathogen management in raspberry, the possible exploitation of avoidance cues used by vine and clay coloured weevils, the genetic cause of crumbly fruit in raspberry, and a long running programme of support for raspberry breeding. Other work supported includes training in methods of barley transformation, the assessment of the effect of adverse weather conditions on distilling quality in wheat and support for a study of techniques to reduce pollution from tramlines in combinable crops. Funding continues on a biennial basis for a keynote speaker at the Crop Protection in Northern Britain Conference next to be held 23–24 February 2010.

Fruit for the Future, 2009.

All meetings organised by the Society were well supported, in virtually every case attracting greater numbers than in previous years.

'Cereals in Practice' was held on 9 July 2009 at the Institute's new Balruddery Farm, and was attended by 207 visitors. This combined event with SAC included static demonstrations of machinery as well as variety and other plant demonstrations.

The 'Fruit for the Future' event held on 16 July 2009 attracted 120 breeders, growers, end-users and processors. The increased attendance was so large that existing facilities are no longer adequate and alternatives are being considered for future years. Research on raspberries, strawberries, blackcurrants and gooseberries was displayed, and a useful opportunity provided for the tasting assessment of prospective new varieties of raspberry.

Cereals in Practice, 2009.

'Potatoes in Practice' was held on 13 August, also located at the new Balruddery Farm. This was attended by over 650 growers, breeders, scientists and advisers, which probably represents about the maximum numbers for such an outdoor event in northern Britain. Support was again provided by Potato Council Ltd, SAC, CSC Crop Protection Ltd, SCRI and the Society.

Potatoes in Practice

Demonstrations on cultivars, agronomy and related research on pests and diseases of the crop, continued to be major features, along with a further increase in static demonstrations of potato crop machinery and other equipment.

The Potato and Soft Fruit Crop Sub-Committees held other half day meetings during the year to provide information on current research and permit interaction between end users, growers, processors and scientists.

The Combinable and Energy Crops winter event at Battleby on 17 February attracted over 70 delegates who listened to an excellent series of presentations on matters of current concern to the cereal industry, including the dramatic changes to pesticide availability.

In the year ahead, the Society will be reviewing its remit, to ensure that it is fit for the 21st century and continues to meet the objectives and aspirations of its members.

Publications

Publications listed between 1 October 2008 and 31 September 2009 are classified in the following manner:

J Papers describing original research in refereed journals.
R Books, book chapters and reviews in books – providing each has been edited externally
P Published proceedings of contributions to conferences or learned societies (including published abstracts)
O Popular articles and unrefereed publications

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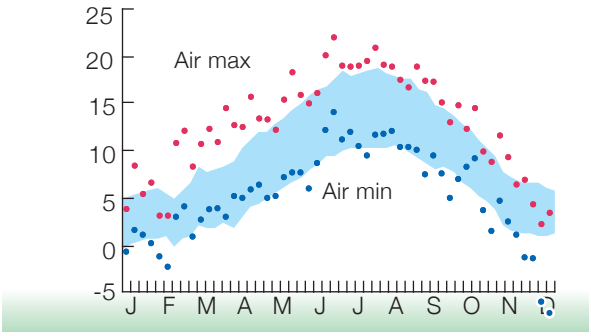
Meteorological Records 2009

Marion Grassie

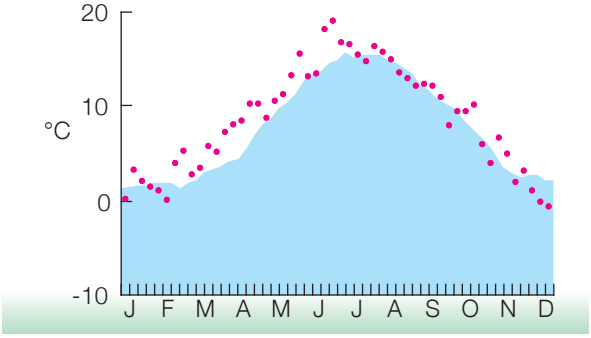
The main features of 2009 were high rainfall, flooding, higher than normal air and soil temperatures and perhaps surprisingly, higher than average sunshine. Outstanding months were March, with record sunshine, warmer temperatures and low rainfall; November with record rainfall; and December which was a particularly cold month breaking a number of our records, held since 1954.

Air temperature



Temperature All months boasted average maximum air temperatures higher than the Long Term Average (LTA), with the exceptions of January, fractionally under the LTA of 5.9°C at 5.8°C, and December, at 4.7°C (LTA 6.7°C). Most significant were March, April and September. The highest maximum air temperature recorded was July's 26.0°C.

10cm soil temperature

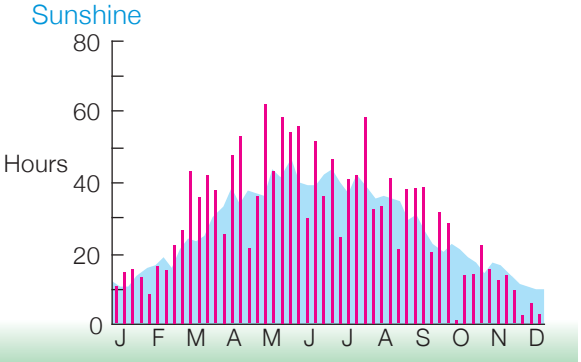


Blue areas on figures indicate long term average 1961–1990

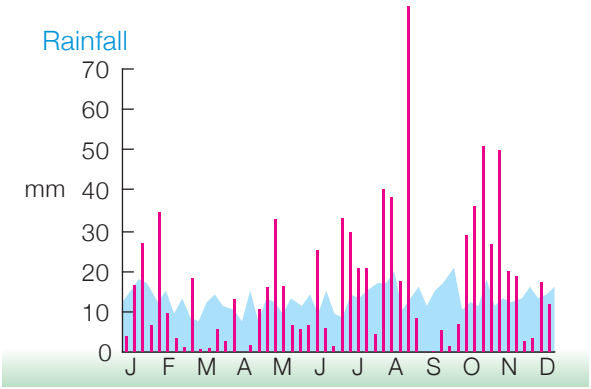
Average minimum air temperatures were all equal to or higher than the LTA with only one exception, December. April's minimum was 5.6°C (LTA 3.7°C). August, with a minimum air temperature of 8.9°C (LTA 5.5°C) was the highest on our records. December's average figure was the lowest on our records at -3.4°C (LTA 1.2°C). The total number of days with air temperature <0°C came to 62, 15 more than the LTA of 47.

Minimum grass temperatures showed mixed results with April, May, and August through to November all displaying higher than expected figures. January to March, June, July and December all showed minimum monthly temperatures below normal. December's LTA figure of -9.2°C was beaten with -11.3°C, but does not compare with the particularly chilly -13.3°C recorded in 2008. The total number of days with grass temperature <0°C (frost) was 125, 9 days fewer than the LTA of 134. Although only August and September escaped frost, most months had fewer nights of frost than expected. December had 31 nights of frost for the first time on our records (LTA 21).

Sunshine

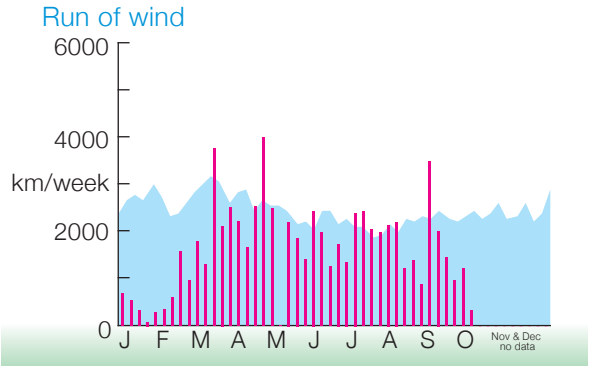


Mean soil temperatures were again higher than the LTA for most months; the exceptions were January and December, where figures were slightly lower than normal.



Sunshine and solar radiation Sunshine figures were fairly mixed with a total of 1523.4 hours of bright sunshine, higher than the LTA of 1411.6 hours. January, March through to June, and September all had more hours of sunshine than expected. March logged the highest figures on our records for the second year running. All other months showed lower than normal sunshine figures, the poorest being December. Solar radiation values were again higher than normal with the exception of August.

Dundee Flower & Food Festival, 2009.



Rainfall As with 2007 and 2008, 2009 is likely to be remembered for its exceptional rainfall. Once again levels were higher than normal, the annual total reaching 845.9mm as compared to the LTA of 664.5mm. Seven months had greater than normal rainfall – the figures being significantly higher, November produced 147.3mm – three times the LTA of 52.1mm. This was the highest on our records and resulted in major flooding across the country. Also of note is the 65.6mm of rain which fell during a single 24 hour period on the 3rd September. This was more than the LTA for the entire month and again resulted in considerable local flooding and the cancellation of the first day of the Dundee Flower and Food Festival for the first time in its 21 year history.

Thunder was reported three times during the year, twice during July and once on 30th December.

Wind On the whole, wind speeds were lower than normal. Worth mentioning are the 10 recorded days of gale (mean wind speeds of 34 knots+) as opposed to 20 in 2008. Also, the unusual occurrence of a funnel cloud was witnessed from SCRI on the 24th August.

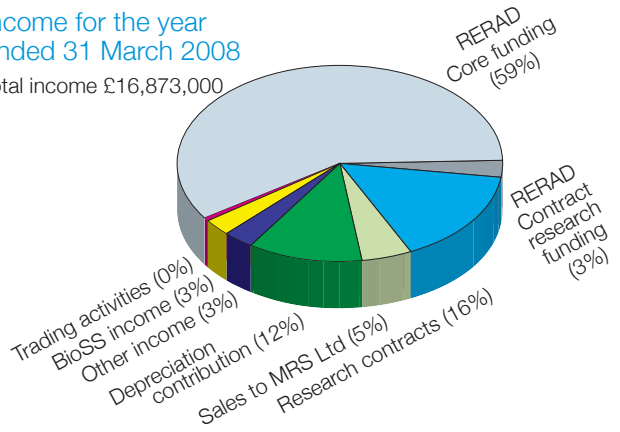
SCRI's weather data is available on our website. You can find a general overview, a data page and a current weather page that displays the present day's data from SCRIs Automatic Weather Station, updated in 15 minute intervals.

Every month, our weather data is featured in the Courier and Dundee Evening Telegraph.

Accounts

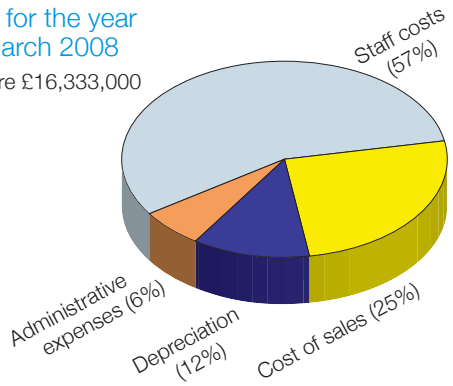
Income for the year ended 31 March 2008

Total income £16,873,000



Expenditure for the year ended 31 March 2008

Total expenditure £16,333,000



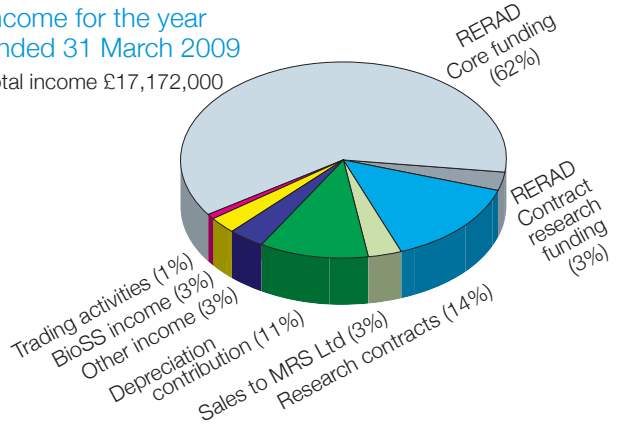
Balance sheet at 31 March 2008

Total value £35,204,000

Assets		Liabilities	
Fixed assets	92 %	Capital reserve	82 %
Stocks	0 %	Income & expenditure account	7 %
Debtors	7 %	Current liabilities	11 %

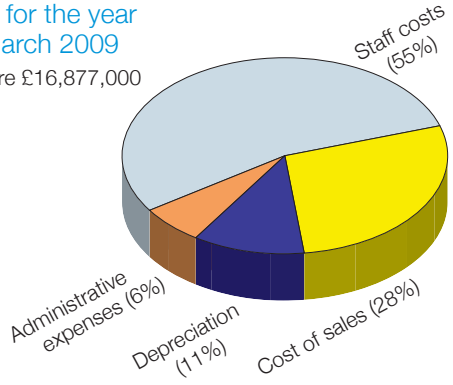
Income for the year ended 31 March 2009

Total income £17,172,000



Expenditure for the year ended 31 March 2009

Total expenditure £16,877,000



Balance sheet at 31 March 2009

Total value £33,655,000

Assets		Liabilities	
Fixed assets	93 %	Capital reserve	81 %
Stocks	0 %	Income & expenditure account	8 %
Debtors	7 %	Current liabilities	11 %

Copies of the statutory accounts can be obtained from the Director of Finance & Corporate Services, SCRI

Staff List as at 1 October 2009

Chief Executive and Institute Director — P J Gregory BSc PhD Hon Dr (Debrecen) CBiol FBS FRASE[4,12,13,14,15]
Director of Science Co-ordination — H V Davies BSc PhD CBiol FBS[1,2,4]
Director of Science Planning — D W Hopkins BSc PhD CBiol[16,17,20,21,22]
Director of Finance and Corporate Services — N G Hattersley BSc PhD ACMA

Genetics

R Waugh BSc PhD (Programme Leader)[3,4]
M M Bayer MSc PhD
N Bonar HNC
A Booth HNC
C Booth BSc
R M Brennan BSc PhD
G J Bryan BSc PhD
X Chen BSc PhD
G P Clark HNC BSc
J Comadran-Trabal BSc
D Cullen BSc PhD
M F B Dale BSc PhD[3]
D Davidson
L Donnelly
A Druka MSc PhD
I Druka
J D Fuller
A Ghatak BSc
S L Gordon HNC
J Graham BSc PhD
B Harrower HND BSc MSc
P Hedley BSc PhD
I Hein MSc PhD
C Hornyik BSc PhD
K Houston BSc MSc PhD
L Jorgensen HND
R Keith NEBS
D Lewandowska BSc PhD
M S Liney HND
M E Looseley BSc MSc PhD
J Lyon
S McCallum
S McClatchey
G McKenzie HND BSc
K McLean BSc
M Macaulay HNC BSc
D F Marshall BSc PhD
H A Mathews
J Middlefell-Williams HNC
I R Milne BSc PhD
L G Milne BSc PhD
J Morris HND BSc
M Myles ONC
A Prashar BSc MSc PhD
G Ramsay BSc PhD[3]
L Ramsay BSc PhD
J Russell BSc PhD
S K Sharma BSc PhD
P D Shaw MSc
C G Simpson BSc PhD
K Smith DipHE
P L Smith BSc
G J Stephen BSc
J Stephens BSc PhD
G E L Swan
J S Swanston BSc PhD CBiol MIBiol
W T B Thomas BSc PhD
N Uzrek BSc
A Weir
G Wilde
S L Williamson BSc
R N Wilson NCH
M R Woodhead BSc PhD
J Yildiz HNC BSc
G R Young HNC

Mylnefield Research Services

H Bull BSc
D Coyle
D Clark
G Duncan BSc
L Ferguson
S N Jennings BSc
J Robertson
V Young BSc

Plant Pathology

L Torrance BSc PhD (Programme Leader)[3]
A O Avrova BSc PhD
C J Barker
V C Blok BSc MSc PhD
P Boevink BSc PhD
J L Brierley BSc PhD
W Burry
M Burton
S N Chapman BSc PhD
P Cock MPhys MSc PhD
D E L Cooke BSc PhD
G H Cowan HNC MSc
A Dolan HNC
E Douglas BSc
B Fenton BSc PhD CBiol MIBiol[3]
G L Fraser
E Gilroy BSc PhD
D C Guy HND
N Holden BSc PhD
A M Holt
S N Humphris HNC BSc PhD
J T Jones BSc PhD[3]
S S Lamond
A K Lees BSc PhD
H Liu BSc MSc PhD
A J Love BSc PhD
J Lynott BSc
S A MacFarlane BSc PhD
W J McGavin BSc
K D McGeachy HNC
J McMillan
G L Malloch DCR BSc PhD
A C Newton BSc PhD
P F Palukaitis BSc PhD[1,5,10]
A J Paterson HND
Y Pitkin BTec HND
L Pritchard BSc PhD
E F O Randall MSc PhD
B Reavy BSc DPhil
W Ridley
A G Roberts BSc PhD[3]
J Shaw BSc
A Smith BSc
J N Squires BSc PhD
J A Stewart HND BSc
L Sullivan BSc
M M Swanson BSc PhD
M Taliansky PhD DSc[11]
J Tilsner BSc PhD
I K Toth BSc PhD[6]
R F Van Toor BSc PhD
E Warden ONC
S Whisson BSc PhD
N A Williams HNC
K M Wright MA PhD
A Ziegler BSc PhD

1 Honorary Senior Lecturer in the University of Dundee
2 Professor, Universities of Cordoba and Malaga
3 Honorary Lecturer, University of Dundee
4 Honorary Professor, University of Glasgow
5 Adjunct Professor, Cornell University
6 Honorary Lecturer, University of Aberdeen
7 Honorary Fellow, University of Edinburgh
8 Honorary Lecturer, University of Strathclyde
9 Honorary Professor, Heriot-Watt University, Edinburgh
10 Honorary Professor, Seoul Women's University
11 Adjunct Professor, Moscow State University
12 Visiting Professor, University of Reading
13 Honorary Professor, University of Dundee
14 Visiting Professor, University of Abertay, Dundee
15 Honorary Professor, University of Edinburgh
16 Visiting Professor, University of Stirling
17 Adjunct Professor, University of Canterbury New Zealand
18 Special Professor, University of Nottingham
19 Visiting Associate Professor, Comenius University Bratislava
20 Visiting Professor, Newcastle University
21 Honorary Senior Research Fellow, University of Glasgow
22 Honorary Fellow, Rothamsted Research

Plant Products and Food Quality

D Stewart BSc PhD (Programme Leader)
C Cognat
S C Conner BSc MSc CChem MRSC
H V Davies BSc PhD CBiol FBS[1,2,4]
I N De Abreu BSc PhD
G Dobson BSc PhD
P M Dobson
L J M Ducreux BSc MSc MPhil PhD
D Grussu
R D Hancock BSc PhD
R Hutchison
E N Kanichukattu
H Kemp BSc PhD
G J McDougall BSc PhD
D McRae ONC
W Meier-Augenstein PhD CChem MRSC
W L Morris BSc MSc PhD
S D A Pont BSc
J Rauscher
H A Ross HNC PhD CBiol MIBiol
L V T Shepherd BSc MSc PhD
T Shepherd BSc PhD
N Stewart BSc
J A Sungurtas HND
M A Taylor BSc PhD
S R Verrall HNC
P G Walker HND
J F Wilkie

Mylnefield Research Services

W W Christie MBE BSc PhD DSc FRSE
K Devlin
F Gunstone BSc PhD DSc FRSE
L Hunter BSc
L Kelly
S Rowbottom ONC HNC BSc CChem MRSC
G Sawers BSc AMRSC
C Scrimgeour BSc MSc
C Traynor BSc CChem MRSC
K Wood

Environment Plant Interactions

P J White BA PhD (Programme Leader)[18,19]
G Banks BSc MSc
G S Begg BSc PhD
A G Bengough BSc PhD [3]
K Binnie BSc
A N E Birch BSc PhD CBiol MIBiol FRES [3]
L K Brown BSc
S Caul HNC
T J Daniell BSc PhD[3]
J Davidson BSc
L Dupuy MSc PhD[3]
R Dye
F Falconer HNC
L Ford BA
T S George BSc PhD
D C Gordon HNC
P D Hallett BSc PhD
C Hawes BSc PhD
D W Hopkins BSc PhD CBiol FBS
R G Hunjan
P P M Iannetta BSc PGCE(S) PhD
S N Johnson BSc DPhil
C Jorna
A J Karley BA DPhil
M Krol MSc
M MacAskill
B M McKenzie BSc PhD
C Mitchell BSc
S M Mitchell BSc
P Neave NC
R Neilson HNC MSc PhD
D M Roberts HND BSc PhD
G R Squire BA PhD
J A Thompson BSc
T Valentine BSc PhD
L Wiesel BSc
J Wishart BSc PhD
G M Wright HNC
M Young HND MSc PG Dip IT

Mylnefield Research Services

S Donn BSc
R E Wheatley BSc PhD

University of Dundee, Division of Plant Sciences

J W S Brown BSc PhD [3,4,13] (Head of Division)
M Alloy-Lleonart
M Armstrong BSc PhD
A Barakate BSc PhD
P R J Birch BSc PhD (Principal Investigator)
T Bukharova
P Daly BSc
A J Flavell BSc PhD (Principal Investigator)
S Gray BSc
C Halpin BSc MSc HDip PhD (Principal Investigator)
T Ho
S F Hubbard PhD (Principal Investigator)
E Huitema
H G Jones MA PhD FIHort (Principal Investigator)
J Kam
S Y Kim PhD
C McClellan
H McLellan
S Manthri
J Marshall BSc DPhil
K Rataj
J A Raven BA PhD HonPhD(Umea) CBiol FBS FRS FRSE (Principal Investigator)
R Shafiei
G G Simpson BSc PhD (Principal Investigator)
M Skelly
M Spensley
N H Syed BSc PhD
S Vivera BSc MSc
Y Wilson BSc
Y Xiao
X Xu

Communication and Information Services

P Taylor MCIPR (Head of CIS)
P Cassidy
S E Collier BSc MA MCLIP
U M McKean MA DipLib
C V Morton BA
S J Neilson DipBiolSci DipPollCon BSc
I R Pitkethly HND
E S Ritch
L Wakefield MA

Information Technology

S Clark HNC MSc (Head of IT)
L H Davidson BA
I Grant HNC
P J R Grimmond BA
R McCreary BSc
L A McGregor BSc
V Pandey BSc
P Smith BSc

Finance and Corporate Services

N G Hattersley BSc PhD ACMA
(Director of Finance and Corporate Services)
S Bell
A J Cartwright BA DMS FCIPD
M Dalziel MA PgDPM MCIPD
R G Davidson
P Duncan
F Ferguson BA GradCIPD
S Forsyth
K L Grant BA
B V Gunn
S Inglis
J Keith
C F Kydd FCCA
L Logie HNC MInstAM(AdvDip)
A Pack BA
W Patterson HND
K Robb
F I F Rowe MA DipNEBOSH Grad IOSH EnvDipNEBOSH
(Safety Quality Environment Manager)
A Sandilands
S Sinclair
M Soutar
E L Stewart
L Young

Engineering and Maintenance

S Petrie BSc (Head of Engineering and Maintenance)
J Anderson
D Byrne
C Conejo
L A Crichton
G J E Ewart
A G Fox
D Gray HNC
K A Henry
R D McLean
I C McNaughton HNC
G Pugh
D J Redford
G C Roberts
J Rowe
W Scott
B Semple

Glasshouse and Field Services

P A Gill HND NEBOSH
(Glasshouse and Field Services Manager)
J Abernethy
P Baird
J R K Bennett
J T Bennett
E Caldwell
M Cook
A G Dobson HNC HND
I Fleming
J M Ford
A C Fuller
M A Grassie HNC BEd
P Heffell ONC
R Keith
M Lipska
J Mason
T A Mason NEBSM
D I Matthew BSc
A W Mills
A D Munro HND
R Ogg
G R Pitkin HND
A M Thain HNC
J K Wilde
D Young

Mylnefield Research Services

N W Kerby BSc PhD CBiol FBS (Managing Director)
L Beaton HNC DMS MBA
A Ross HNC CPP
J B Snape MA MSc PhD CBiol MIBiol MBA
H Wilson HNC

Biomathematics and Statistics Scotland

D A Elston BA MSc PhD (Director of BioSS)

King's Buildings, University of Edinburgh

C A Glasbey MA DipMathStats PhD DSc MISI
(Head of Group)[7,8,9]
A Butler BSc PhD
S Catterall BA MSc PhD
J M Dickson BSc
D Glancy
E M Heyburn MA
D Husmeier BSc PhD
G T Innocent
H R Kettle BSc MSc PhD
M A M Kirkwood DA
A D Mann BSc
G R Marion BSc MSc PhD
I J McKendrick BSc PhD
M Nath BSc MSc PhD
I M Nevison MA
D Nutter BSc
J Polechova BSc MSc PhD
A M I Roberts BSc MSc
Y Song BSc MSc PhD
L Spezia BSc PhD

West of Scotland Unit, Hannah

S Brocklehurst BSc PhD

Environmental Modelling Unit, Macaulay

D A Elston BA MSc PhD (Head of Group)
M J Brewer BSc PhD
E I Duff BSc
J M Potts BSc MSc PhD

Aberdeen Unit, Rowett

G W Horgan BA MSc PhD (Head of Group)
G Holtrop MSc PhD
C D Mayer MSc PhD

Dundee Unit, SCRI

C A Hackett BA DipMathStats PhD (Acting Head of Group)
C Alexander BSc PhD
K M MacKenzie BSc MSc PhD
F G Wright BSc MSc PhD

Visiting workers

Name	Country of origin	Programme	Month/yr of arrival	Length of stay
N Aberdein	UK	PPFQ	Sep-09	5 mth
A Ahmad	Pakistan	EPI	Apr-09	6 mth
B Alhusen		GEN	Sep-09	2 wks
M Al-Khairulla	UK	PPFQ	Sep-09	5 mth
A Alliaume	France	EPI	May-09	3 mth
S Apparow	Malaysia	GEN	May-09	3 mth
A Artaux	France	EPI	Aug-09	4 mth
M Ashfaq	Pakistan	PP	May-09	8 mth
A Augustine	India	GEN	May-09	1 yr
I Badjakov	Bulgaria	PPFQ	Apr-09	3 wks
P Baranowski	Poland	UoD	Feb-09	2 wks
K Becker	UK	EPI	May-09	3 mth
E Blixt	Sweden	PP	Feb-09	4 mth
A Block	USA	UoD	May-09	3 mth
J Bruce	UK	EPI	Sep-09	9 mth
M A R Cervera	Spain	PPFQ/MRS	May-09	3 mth
B N Chung	Korea	PP	Apr-09	6 mth
P Connelly	UK	PPFQ	Sep-09	5 mth
I Dawson	UK	GEN	Dec-08	7 mth
M De Sain	Netherlands	PP	Apr-09	1 mth
V Delcroix	France	EPI	Jun-09	3 mth
P Dennis	UK	EPI	Apr-07	3 yrs
A K Dev	India	EPI	Oct-08	5 mth
P Dyer	UK	PP	Sep-09	8 mth
P Dyer	UK	UoD	Jun-09	2 mth
J Elder	UK	CIS	Sep-09	2 mth
S Engelhardt	Germany	PP	Feb-09	2 yr
S Ewert	France	GEN	Sep-09	6 mth
H Fankem	Cameroon	EPI	Feb-09	10 mth
J Fikowicz-Krosko	Poland	PP	Jul-09	1 mth
L Forster	UK	EPI	Jul-09	1 mth
A Galbraith	UK	UoD	Apr-09	5 mth
P Gandham	India	PP	Aug-09	5 mth
E Gil	Spain	EPI	Jul-09	1 mth
A Gill	India	EPI	Dec-08	5 mth
D Gokhale	India	PPFQ	Aug-09	3 mth
K Goszcz	Poland	PPFQ	May-09	5 mth
K Graham	UK	UoD	Feb-09	3 wks
A Gras	France	EPI	Jun-09	3 mth
D Grussu	UK	PPFQ	Jan-09	5 mth
J Guzy-Wrobelska	Poland	GEN	Feb-09	3 mth
C Hale	UK	EPI	Jul-09	2 mth
M Haq	Bangladesh	UoD	Jul-09	2 mth
A Hartmann	Germany	PPFQ	Jul-09	3 wks
J Helps	UK	EPI	May-09	4 mth
A Hernandez	USA	UoD	Mar-09	9 mth
E K James	UK	EPI	Jan-09	1 yr
A John	India	PP	May-09	4 mth
F John	India	EPI	May-09	4 mth
M Johnston	UK	EPI	Jul-09	2 mth
M Kaczmarek	Polant	UoD	Sep-09	1 yr
E N Kanichukattu	India	PPFQ	Jun-09	4 mth
J Kevrele	UK	PPFQ	Oct-08	6 mth
T Kikuchi	Japan	PP	Oct-08	4 mth
P Kongprakhon	Thailand	GEN	Mar-09	4 mth
A Kumar	India	PPFQ	Apr-09	5 mth
S Kurian	India	PP	May-09	6 mth
B Kusenda	Slovakia	GEN	Oct-08	2 wks
S Labibida	Syria	GEN	Jul-09	3 mth
R Lamarque	France	PP	Jun-09	2 mth
C Lambert	France	EPI	Jun-09	2 mth
J Lamont	UK	UoD	Sep-09	1 yr
A Landau	Argentina	GEN	May-09	2 mth
T Lemmermeyer	Germany	PP	Oct-08	1 mth
M Lisowska	Poland	PP	Jun-09	2 mth
M Liu	China	EPI	Apr-09	2 wks
V Lund	UK	PPFQ	Dec-08	2 mth
M Maronova	Slovakia	GEN	Oct-08	2 wks
P Martin	France	EPI	Mar-09	5 mth
R Martin	UK	PP	Jul-09	1 mth
I Martinussen	Norway	PPFQ	Apr-09	2 wks
L McCormick	UK	UoD	Sep-09	6 mth
F McLeod	UK	EPI	Jun-09	4 mth
J Molmann	Norway	PPFQ	Apr-09	2 wks
M Mucci	Italy	PP	Feb-09	4 mth
S Mucyo	Rwanda	PPFQ	May-09	4 mth
S Nunsavathu	India	PPFQ	May-09	5 mth
M Opik	Estonia	EPI	Feb-09	3 wks
J Papuchon	France	EPI	Jun-09	3 mth
L S Pardo	Spain	PPFQ	Jan-09	4 mth
A Paul	India	EPI	May-09	4 mth
S Perez Gomez	Spain	GEN	Aug-09	4 mth
H Pietrykonska	Poland	GEN	Sep-09	2 wks
B Pindelski	Poland	IT	Feb-09	4 mth
J Ponchart	France	PP	Jan-09	7 mth
C Primeau	Denmark	PPFQ	Jul-09	2 mth
A Przetakiewicz	Poland	PP	Jun-09	2 mth
T Pulickal	India	PPFQ	Apr-09	4 mth
L Pylypenko	Ukraine	PP	Jan-09	3 mth
N Rabourdin	France	EPI	Jun-09	3 mth
D Raczynska	Poland	GEN	Sep-09	2 wks
R Radhakrishnan	India	PP	Apr-09	5 mth
M B Ramos	Spain	PP	Oct-08	7 mth
S Reid	UK	UoD	Jun-09	9 mth
E Repplinger	France	EPI	Apr-09	2 mth
C Rizza	Italy	PP	Oct-08	2 mth
L Robertson	UK	PP	May-09	3 wks
K Ross	UK	EPI	Sep-09	7 mth
R Rothenberger	Germany	PP	Mar-09	6 mth
J Russell	UK	PP	Sep-09	9 mth
B Sable	Canada	EPI	Jan-09	3 wks
R Sallepalli	India	PPFQ	Apr-09	5 mth
J Samson	UK	CIS	Jan-09	3 mth
A S Samuel	India	UoD	Sep-09	1 yr
M C Scandura	Italy	PPFQ	Jun-09	4 mth
V Schnepf	Germany	PP	Sep-09	4 mth
S Scibetta	Italy	PP	Oct-08	2 mth
C Sharma	India	PPFQ	Apr-09	5 mth
A Snadden	UK	UoD	Jul-09	9 mth
P K Sreekumari	India	PP	May-09	5 mth
O Stasik	Ukraine	UoD	May-09	3 mth
C Stushnoff	USA	PPFQ	Oct-08	2 mth
B Sun	China	EPI	Aug-08	1 yr
J Sun	China	EPI	Jan-09	2 mth
A Tahir	Pakistan	UoD	Sep-09	1 yr
H A F A Thahar	India	PP	Apr-09	5 mth
Z Tian	China	PP	Nov-08	11 mth
A Tite	France	EPI	Jun-09	3 mth
A Tondelli	Italy	UoD	Apr-09	2 wks
M Tyagi	Portugal	PPFQ	Sep-09	3 wks
E Udugbezi		UoD	Apr-09	5 mth
C Vagne	France	GEN	Jun-09	5 mth
Y Valdes	Cuba	PP	Jan-09	1 mth
V Vasukuttan	India	PPFQ	Dec-08	4 mth
A Vaughan	UK	EPI	Jun-09	1 mth
V Vendramin	Italy	GEN	Apr-09	1 mth
A Visiani	Spain	GEN	Feb-09	3 mth
U Vrhovsek	Italy	PPFQ	Feb-09	3 wks
N Walker	UK	EPI	Sep-09	6 mth
R Wenchel	Germany	PP	Feb-09	3 mth
L Whiteside	UK	UoD	Sep-09	6 mth
J Wilson	UK	PP	Sep-09	9 mth
X Wu	China	EPI	Nov-08	10 mth
C Y Yang	Korea (South)	PP	Jul-09	3 mth
W Yang	China	PPFQ	Apr-09	5 mth
C Yule	UK	CIS	Sep-09	3 wks
Z Zhang	China	GEN	Oct-08	9 mth

Postgraduate students

Name	Programme	Project Title
Aqueel Al-Abedy	PP	Studies on *Potyvirus* resistance in *Solanum Phureja.*
Ahmad Al-Mrabeh	PP	*Potato Virus Y* and aphid transmission.
Ananthi Anandanadesan	UoD/EPI	Mathematical modelling of the spatio-temporal dynamics of aphid–parasitoid–plant virus interactions.
Sandra Bacon	PPFQ	Potentiation of the action of novel nutrient regulators of the longevity factor FOXO1a by the trace metal zinc.
Gillian Banks	EPI	Dynamics for feral oilseed rape populations and the impacts on associated insect communities.
Nathalie Bernaert	PPFQ	Metabolite profiles of leek in function of genetic variation, breeding and processing techniques.
Rachel Berry	PPFQ	The real uncertainty of stable isotope data for provenancing of humans and drugs.
Susan Breen	PP	Translocation of effector proteins into host plants.
Hazel Bull	GEN	Development and characterisation of a meta-population of *Hordeum spontaneum* introgression lines into cultivated barley.
Andrew Burgess	UoD/EPI	Mathematical modelling of disease dynamics in host–parasitoid systems.
Raymond Campbell	PPFQ	Genetics of carotenoid levels in potato tubers.
Alison Chapman	PP	The changing *Phytophthora infestans* population: implications for late blight epidemics and control.
Xiaoyun Chen	EPI	Biodiversity and soil food web activity in different managed grasslands.
Emily Clark	EPI	Multitrophic factors influencing aphid vector competence in a spatially heterogeneous environment.
Katy Clark	EPI	Does mother know best? Is host plant selection by above ground insects influenced by below ground herbivores?
Hannah Clarke	UoD/EPI	The role of bacterial secondary symbionts of *Macrosiphum euphorbiae* in the dynamics of multitrophic interactions.
Emma Coates	PPFQ	Anti-cancer effects of soft fruit phytochemicals.
Nicky Cook	UoD/EPI	Population genetics of fernland sawflies.
Marion Cubitt	PP	A systems approach to virulence regulation in *Pectobacterium*.
Paul Daly	UoD/GEN	Manipulation of lignin biosynthesis in barley.
Jayne Davis	EPI	Molecular interactions of potassium deficiency and pathogen resistance in barley.
Sherine Deakin	PPFQ	Antioxidant effects of phytochemicals in conditions of oxidative stress: impact on endothelial cell survival and function.
Wenni Deng	EPI	Engineering novel geotextiles form an understanding of the dynamic properties of seed coat mucus.
Ralf Dietrich	UoD/EPI	Root soil dynamics: New ways of studying roots in a changing climate.
Helen Downie	EPI	3D imaging of root particle interactions using optical projection tomography and x-ray microtomography.
Natasha Duckett	EPI	Soil reinforcement using plant roots: A sustainable alternative to traditional slope stabilisation.
Daniel Dzidzienyo	GEN	Manipulation of self-incompatability in diploid potato species.
Alexandre Foito	PPFQ	Development of metabolomics based methods to benefit marker assisted breeding in perennial ryegrass.
Fiona Fraser	EPI	Temperature responses of soil nitrogen transformations.
Joanna Fyans	UoD/PP	The role of protein transport in the pathogenicty of *Streptomyces spp*.
Madeline Giles	EPI	Where does denitrification occur in the rhizosphere?
Varun Gopalakrishnan	PP	Acquisition and transmission of Potato mop top virus by *Spongospora subterannea*.
Clement Gravouil	PP	Multiple disease interactions on cereals and interactions with other crop environment organisms.
Severine Grouffaud	PP	Translocation of *Phytophthora* effectors and their manipulation of host plant disease resistance.
Miriam Herold	EPI	Plant roots as drivers of denitrification.
Gerald Hochshartner	GEN	Application of a novel snoRNA marker system in plant evolution and systematics.
Lydia Hunter	PP	Role of potato RNA-dependent RNA Polymerase 1 in virus resistance.
Ning Jiang	GEN	Linkage disequilibrium based mapping of complex traits in crops.
Florian Jupe	GEN	Utilising next generation sequencing to clone and characterise durable potato resistance genes.
Angzzas Kassim	GEN	Genetic and environmental control of anthocyanin and volatiles in red raspberry.
Pavel Kerchev	PPFQ	Influence of ascorbic acid on plant aphid interactions.
David Lloyd	GEN	Mapping genes and QTLs linked to flavour and texture in potatoes.
Kenneth Loades	EPI	Quantifying the role of fibrous roots on soil reinforcement.
Marta Maluk	UoD/GEN	Improving barley for biofuel production – investigating the roles of CCR and 4CL in lignin biosynthesis.
Susan McCallum	GEN	Linking phenotype to genotype for fruit quality traits in raspberry.
Lindsay McMenemy	EPI	Cooperation between plant enemies – do raspberry viruses attract more aphid vectors?
Stefania Pasare	PPFQ	The regulation of isoprenoid metabolism in *Solanaceae* crop plants.
Katarzyna Rataj	UoD/GEN	Functional characterisation of the protein interaction domain of FPA.
Namrata Reetoo	UoD/GEN	Controlling *Arabidopsis* RNA binding proteins with phosphorylation.
Christelle Robert	BioSS	Prediction of promoter binding sites and transcriptional regulatory networks in two gamma-proteobacterial pathogen genomes.
Sonja Schmidt	EPI	Microtomography in soil root interactions.
Zulkifli Ahmad Bin Seman	GEN	Functional and evolutionary characterisation of host genes targeted by *Phtyophthora infestans* effectors and defence associated candidate genes.
Jane Shaw	PP	The role of Cajal bodies in the nucleolus in plant virus infection.
Marcin Skiba	EPI	Biological nitrification inhibition in the rhizosphere of temperate arable plants.
Nithya Subramanian	GEN	Increasing mineral delivery through potatoes.
Hui Tan	PP	Dissection of the *Pectobacterium* virulence quorum sensing regulation.
Rosalind Mary Taylor	PP	Ubiquitin-proteasome directed proteomic approach to dissect biotic stress signalling in plants.
Amar Thirugnanasambandam	PP	Role of seed-borne infection in *Rhyncosporium* and *Ramularia* epidemics in barley.
Maja Thorsen	EPI	Biological mechanisms involved in stabilising sandy soils of the machair.
Stephanie Vink	EPI	Functional soil ecology and conservation in the machair in relation to changing land management.
Lea Wiesel	EPI	Caesium uptake by roots of *Medicago* plants.
Tobias Wojciechowski	GEN	Root development in semi dwarfing lines of wheat and barley.
Han Xiao	PPFQ	Function of polyphenols in chemoprevention.
Vanessa Young	MRS	Genetic analysis in a commercially relevant cross and application of markers in a tetraploid breeding programme.
Dzeti Zait	GEN	Sensory and compositional analysis of flavour in red raspberry.
Monica Zwirek	UoD/GEN	Improving barley for biofuel production – efficient transformation for lignin manipulation.

Honorary Research Fellows

Professor Richard Abbott BSc PhD
Dr Pamela Anderson PhD
Dr Hugh Barker BSc PhD
Professor Geoffrey J Barton BSc PhD
Professor Jim Beynon BSc PhD
Professor Stephen Blackmore BSc PhD FLS CBiol FBiol FRSE
Professor Mike Blatt BSc PhD FRSE
Dr Meredith Bonierbale PhD
Dr Fraser Bransby BA MA PhD
Dr William W Christie MBE BSc PhD DSc FRSE
Professor Sir Philip Cohen FRS FRSE
Professor Pierre de Wit PhD
Professor Pete Downes OBE FRSE MIBiol PhD
Dr Jim M Duncan MBE BSc PhD
Dr Roger Ellis BSc PhD
Dr Andy Flavell Bsc PhD
Professor Geoff Gadd BSc PhD DSc FBS FLS
Professor Mary Gibby BSc PhD FRSE FRSA
Professor Frank Gunstone BSc PhD DSc FRSC FRSE
Professor Claire Halpin BSc MSc H Dip PhD
Professor Bryan Harrison CBE BSc PhD DAgFor FRS FRSE
Dr John Hayes BSc PhD
Professor John Hillman BSc PhD DSc FLS CBiol FBS FIHort FCMI SHM FRAgS FRSE
Dr Pete Hollingsworth BSc PhD
Dr Steve Hubbard MSc DIC(London) DPhil (Oxon)
Professor Lindsey Innes OBE BSc PhD DSc FRSE
Professor Hamlyn Jones MA PhD FIHort
Professor Peter Langridge BSc PhD
Dr William H Macfarlane Smith BSc PhD CBiol MIBiol FIMgt
Professor Gordon Machray BSc PhD
Mr George R Mackay MBE BSc MSc CBiol FBS
Dr Donald K L MacKerron MBE BSc PhD
Professor Tom Meagher BA PhD
Professor Andrew J Millar BA PhD
Professor Hugh Nimmo MA PhD FRSA
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Dr Michel Pérombelon MBE PhD MSc BSc Dip Agric
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Dr David J Robinson MA PhD
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Professor Janet Sprent OBE BSc DSc PhD ARCS FRSE
Dr Alyson Tobin BSc PhD
Dr Pieter van West MSc PhD
Professor Roberto Viola DipAgrSci PhD
Mr David Walker OBE
Dr Brian Williamson BSc MSc PhD DSc

SCRI Research Programme ongoing as at 1 October 2009

The research programme is commissioned by RERAD (Scottish Government: Rural and Environment Research and Analysis Directorate) and a variety of other funders. The list contains the body that awarded the grant and the title of the project and, in the case of RERAD, the commissioning number.

RERAD Core – Programme 1

Workpackage 1.1	Barley Genetics
Workpackage 1.2	Potato Genetics
Workpackage 1.3	Soft Fruit Genetics & Pathology
Workpackage 1.4	Barley Pathology
Workpackage 1.5	Potato Pathology
Workpackage 1.7	Sustainable Crop Systems

RERAD Contract Research Funding

SCR/849/08	Support for additional knowledge exchange activities.
SCR/918/07	Genomics-assisted dissection of barley morphology and development.
SCR/919/07	*Dickeya dianthicola* – a threat to Scottish seed potatoes.
SCR/921/09	Cell wall lignin programme: manipulating lignin to improve biofuel conversion of plant biomass.
SCR/927/09	Emerging threat to Scottish potato production posed by *Dickeya solani.*
BSS/037/08	Scottish badger survey.
BSS/845/06	Epidemiology, population, health and infectious disease control.

External research contracts

Biotechnology and Biological Sciences Research Council (CSI)	Optimising wheat grain shape for improved processing quality.
BBSRC (CSI)	Exploiting the *Phytophthora infestans* genome to identify gene targets for sustainable potato protection.
BBSRC (CSI)	The establishment and application of a forward genetic resource for the development of efficient breeding strategies in grass and cereals.
BBSRC LINK	Association genetics of UK elite barley.
BBSRC LINK	Role of inoculum sources in *Rhynchosporium* population dynamics and epidemics on barley.
BBSRC (via University of Dundee)	LoLa: What are the roles of oomycete RXLR effectors in the establishment of plant disease?
BBSRC (via University of Birmingham)	LoLa: Meiosis in barley: manipulating crossover frequency and distribution.
Bioforsk	Systems experiments.

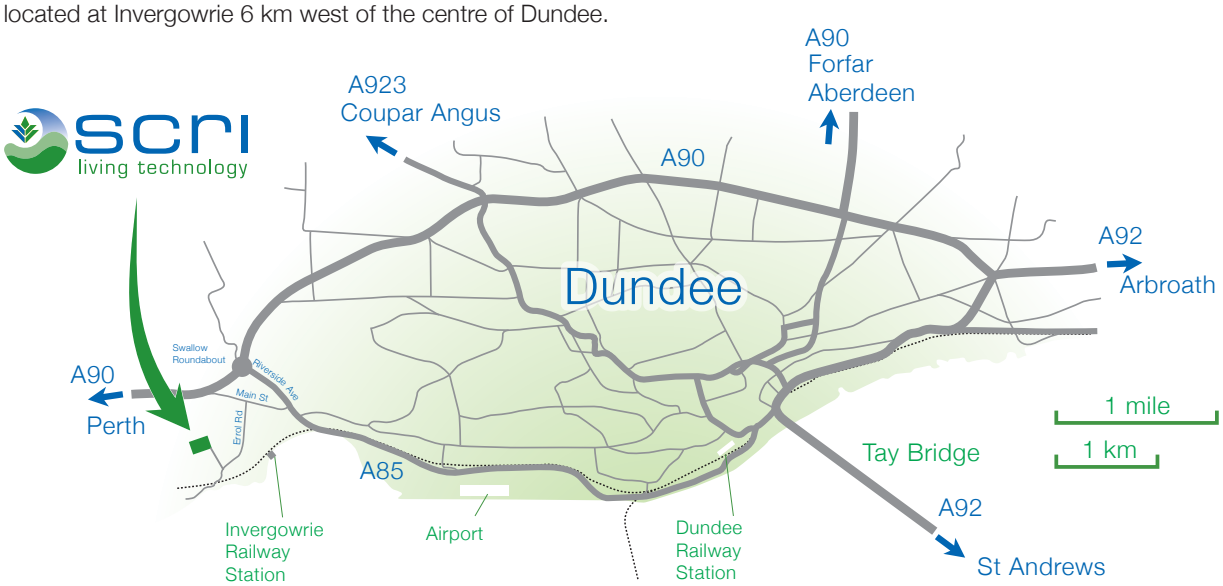
Bioforsk	Plant metabolites for healthy plants and healthy people.
British Council	Analysis of the interaction between the pine wood nematode *Bursaphelenchus xylophilus* and the maritime pine *Pinus pinaster.*
British Ecological Society	Climate change in the underworld: how elevated CO_2 affects root–herbivore interactions.
Carnegie Trust	Trophic cascades in a changing climate: the impact of elevated CO_2 on above– and below–ground interactions.
Carnegie Trust	The role of bacterial secondary symbionts of cabbage aphids on aphid-parasitoid interactions in Scotland.
Centre for Ecology & Hydrology (via Department for Environment Food and Rural Affairs (Defra))	Use of 'UKCIP08 scenarios' to determine the potential impact of climate change on the pressures/threats to soils in England and Wales.
Commercial	Brassica breeding.
Commercial	Soft fruit analysis.
Commercial	Potato breeding.
Commercial	Blackcurrant breeding.
Commercial	Lipid analysis.
Commercial	Barley analysis.
Commercial	Soil and water conservation.
Defra/Home-Grown Cereals Authority (HGCA)	GREENGRAIN: Genetic reduction of energy use and emissions of nitrogen in cereal production (LINK).
Defra LINK (via ADAS)	TRAMLINES: Practical cost-effective techniques to reduce pollution from tramlines in combinable crops: a field and catchment scale evaluation.
Defra LINK (via SAC)	CORACLE: Control of Ramularia leaf spot in a changing climate.
Defra/RERAD	Integrated pest and disease management for high quality protected raspberry production.
Estacion Experimental de Aula Dei, CSIC, Spain	Immunogold localisation of antioxidant proteins in legume nodules.
European Union (EU)	EURASNET: European alternative splicing network.
EU	EU-SOL: High quality solanaceous crops for consumers, processors and producers by exploration of natural biodiversity.
EU	BIOEXPLOIT: Exploitation of natural plant biodiversity for the pesticide-free production of food.
EU	DEVELONUTRI: Development of high throughput approaches to optimise the nutritional value of crops and crop-based foods.
EU	GENBERRY: European small berries.
EU	SPICY: Smart tools for prediction and improvement of crop yield.
EU	*Triticeae* Genome: Genomics for *Triticeae* improvement.
EU	PLAPROVA: Plant production of vaccines.
EU	BrainHealthFood: Bioactive compounds from blackcurrant processing waste for brain health.
EU	Meiosys: Systematic analysis of factors controlling meiotic recombination in higher plants.
EU Marie Curie	Role of arbuscular mycorrhizal fungi on the accumulation of radiocaesium by plants.
EU Marie Curie	Managing insecticide resistance in aphids in Scotland.

European Science Foundation	Exploiting genomics to understand plant-nematode interactions.
Food and Environment Research Agency	Identification and reduction of risks posed by Potato Ring Rot disease to the Scottish potato industry.
French National Institute for Agricultural Research (INRA)	Global change at the microbial scale – effects of climate change on microbial decomposition and modulation of physical structure of soil.
HGCA	Fungicide performance information for barley growers.
Horticultural Development Council (HDC)	Developing techniques to manage raspberry leaf and bud mite in tunnel produced raspberry.
International Maize and Wheat Improvement Center CIMMYT	Genomic dissection of tolerance to drought stress in wild barley.
Medical Research Council (via University of Dundee)	New geotechnical approaches to soil biological processes.
Ministerio de Educacion y Cienca (CICYT) in Spain	Study of the effect of the treatment with methyl jasmonate on the bioformation of chiral volatile compounds in vegetal foods.
Nairns	Knowledge transfer partnership.
Natural Environment Research Council (via University of Stirling)	Microbial diversity in Antarctic soils.
Norwegian Research Council	Metabolic profiling of *Rubus* (cloudberry and raspberry): effect of inheritance and environment on phytochemicals beneficial to human health and the identification of viable targets for nutritional enhancement.
Potato Council Ltd	Independent variety trials.
Potato Council Ltd	GB late blight populations: monitoring and implications of population changes.
Potato Council Ltd	Informing management of potato diseases through epidemiology and diagnostics.
Potato Council Ltd	Aphids and virus transmission in seed potato crops.
RERAD	Whole genome and interaction transcriptome sequencing of the barley pathogen *Rhynchosporium secalis.* (SCR/922/08)
RERAD	Study of the epidemiology of *Phytophthora ramorum* and *Phytophthora kernoviae* in managed gardens and heathland in Scotland.
RERAD/Defra/Potato Council Ltd	Sequencing the 'gene space' of potato chromosome IV, comparative analysis with tomato and development of a gene-based mapping platform. (SCR/920/08)
RERAD/GSK (HortLink)	Development of high profile germplasm for UK production of blueberries.
RERAD/HDC (HortLink)	Developing breeding and selection tools to reduce spoilage of soft fruits and wastage in the supply chain.
RERAD/Rothamsted International LINK	Producing low acrylamide risk potatoes.
Rothamsted International	Selecting indigenous phosphate solubilising fungi (*Aspergillus, Penicillium*) for crop improvement in nutrient deficient soils of Cameroon. (African Fellowship)
Royal Society	Genetic control of lateral root development stimulated by rhizosphere nematodes.
Royal Society	Transcript profiling of meristem activation in potato using the POCI microarray.
Royal Society	A novel caspase-like protease for plant programmed cell death (PCD).
Royal Society of Edinburgh	RSE/Scottish Executive Personal Fellowship.

Rural Development Administration of Korea	Development of manipulation techniques of plant viruses for the development of multiple virus resistant horticultural crops.
Scottish Enterprise	Additive-free treatments for shelf-life extension of minimally processed foods.
Scottish Enterprise	Improving transformation efficiency in barley using a novel method that protects Agrobacterium-mediated gene transfer from attack by caspases.
Scottish Enterprise	A platform enabling technology to characterise plants for their therapeutic potential: anti-inflammatories from *Capsella* as a model.
Scottish Funding Council (SFC)	Scottish Bioinformatics Research Network (SBRN) maximising bioinformatics infrastructure for Scottish Health, Agriculture and Industry.
Swedish University of Agricultural Science	Characterisation of efficient symbionts via microbial isolation and root nodule structure: a comparison of N_2-fixing legumes from an island (Scotland) with those from a continental ecosystem (Sweden).
Teagasc	Development of metabolomics based methods to benefit marker assisted breeding in perennial ryegrass.

Directions to SCRI

SCRI is on the east coast of Scotland, midway between Edinburgh and Aberdeen.
It is located at Invergowrie 6 km west of the centre of Dundee.



By road

From Dundee: Leave the city in a westerly direction along Riverside Drive and Riverside Avenue, towards Perth (A85). Take the left hand turn into Invergowrie, continue past the shops and the Post Office then turn left into Errol Road, which is signposted for SCRI. Follow the road round a sharp right hand bend. The entrance to SCRI is marked with a sign at the foot of the drive on your right.

From Aberdeen: Take the A90 south to Dundee, following the Kingsway around the city in the direction of Perth to the Swallow/Landmark Hotel roundabout. Turn left into Riverside Avenue (signposted for the city centre A85) and take the next on the right signposted for Invergowrie. Follow Main Street past the shops and the Post Office taking the next left into Errol Road, signposted for SCRI. Follow the road round a sharp right hand bend. The entrance to SCRI is marked with a sign at the foot of the drive on your right.

From Perth: Take the A90 in an easterly direction to Dundee to the roundabout at the junction with the A85. Turn right into Riverside Avenue (signposted for the city centre A85) and take the next on the right signposted for Invergowrie. Follow Main Street past the shops and the Post Office taking the next left into Errol Road, signposted for SCRI. Follow the road round a sharp right hand bend. The entrance to SCRI is marked with a sign at the foot of the drive on your right.

By bus

Invergowrie is served by the 16 and 77 bus routes. There are bus stops on Main Street, Station Road and Errol Road and there is a footpath to SCRI between the houses on Errol Road. For information on travelling in Dundee visit the Dundee Travel Information website. For bus timetables and information see the Stagecoach Bus website.
www.dundeetravelinfo.com
www.stagecoachbus.com

By train

Regular trains from Glasgow, Edinburgh, London and other UK cities run to Dundee. Infrequent trains stop at Invergowrie
www.nationalrail.co.uk

By air

Air France runs regular flights between London City and Dundee airports as part of its CityJet service. Flybe flies to Belfast City and Birmingham International airports from Dundee.
www.airfrance.co.uk
www.flybe.com

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