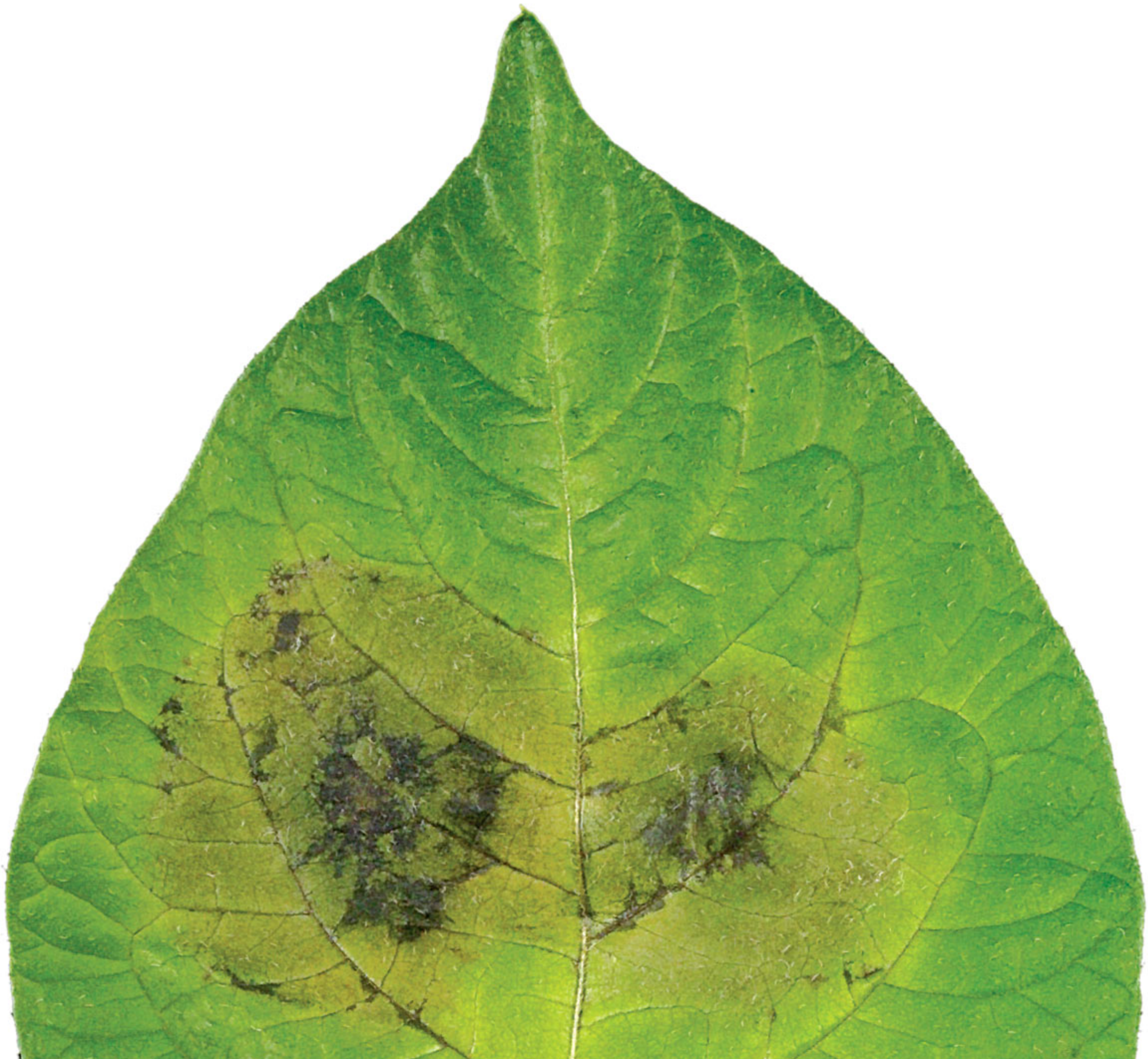
scri
living technology

Annual Report 2006



Governing Board

Auditors : Deloitte & Touche LLP, Saltire Court, 20 Castle Terrace, Edinburgh EH1 2DB.

Solicitors : Thorntons WS, 50 Castle Street, Dundee DD1 3RU.

Banking : Bank of Scotland, P.O. Box 9, 2 West Marketgate, Dundee.

Patent Agents : Murgitroyd & Co, 373 Scotland Street, Glasgow.

Scottish Crop Research Institute
Invergowrie, Dundee DD2 5DA, Scotland, UK.

A charitable company limited by guarantee. Registered, Scotland No. 29367 at the above address.
Recognised by the Inland Revenue as a Scottish Charity No: SC006662

Telephone : +44 (0)1382 562731
Fax : +44 (0)1382 562426
Electronic Mail: mail@scri.ac.uk
Website: www.scri.ac.uk/

Editor : S. Stephens
Graphics and Design : I.R. Pitkethly
Photography : S.F. Malecki

ISSN 0263 7200
ISBN 0 905875 23 0

scri
living technology

Annual Report 2006

Contents

Introduction

Peter J. Gregory

Welcome to this report of the year 2006 at SCRI. From my perspective it was a year of thirds – the first part spent completing the science strategy and accompanying finance, estates, human resource and communications strategies; the second part ensuring that the research commissioned by our major customer, the Scottish Executive Environment and Rural Affairs Department (SEERAD), got underway; and the last part dealing with issues affecting the longer-term sustainability of the Institute including restructuring some elements of our science and service programmes. The last third was clearly a difficult period as we stopped some long-standing activities, and I am grateful to all staff for their patience and understanding as we undergo that necessary change.

This year also saw a major change in the way that SCRI is funded by its major customer, SEERAD. From 1 April 2006, SCRI no longer receives a block grant but is contracted to contribute to agreed programmes of research with agreed outputs and outcomes. This change of funding model, together with new requirements under Scottish law applying to charities, mean that SCRI is definitely no longer a “SEERAD Institute” but a research institute whose major customer is (and will continue to be for the foreseeable future) SEERAD. We have indicative funding from SEERAD for several five-year workpackages, some of which SCRI is responsible for delivering alone, but others are in partnership with the Macaulay Institute and Scottish Agricultural College. SCRI is particularly grateful to Professor Janet Bainbridge, Professor John Porter and Mr Douglas Morrison for agreeing to be external members of the Advisory Group overseeing the development of the workpackage research and delivery of the contracted outcomes. Simultaneously, we are working hard to broaden the base of funding, and were pleased to receive funding from the BBSRC Crop Science Initiative for three projects involving SCRI, and funding to lead a study of the barley genome involving European partners.

2006 was the first full year of operation of our four new science programmes, and we welcomed to the Institute Professor Philip White as Programme Leader for Environment Plant Interactions and Professor David Hopkins as Director of Science Planning. While the context of our work continually changes, we have continued to do excellent research and to fulfil our vision and mission. Details are in the narrative that follows, but I should like to draw particular attention to the progress that has been made to determine the persistence of GM herbicide tolerance traits in the environment, which has informed government policy on the management of GM crops, and the use of genome sequencing (combined with bioinformatics and functional genomics techniques) on *Pectobacterium atrosepticum* (formerly *Erwinia carotovora* spp. *atroseptica*) that have led to new insights into how this bacterium survives when no potatoes are present, and deepened our understanding of quorum sensing. Substantial progress has also been made in analysis of the barley genome, with the publication of results from elite northwest European barley cultivars demonstrating that repeated outcrossing has reduced the extent of linkage disequilibrium to a level where false positive associations of genes and traits is unlikely; this means that it ought to be possible to identify candidate genes for traits, and to develop markers for their selection during breeding. Our research on human health and nutrition continues to expand with the finding that ellagitannins from berry extracts had significant anti-cancer effects in cultured cancer model cells, and that raspberry extracts were effective against the initiation, growth and invasiveness of colon cancer cells. Who knows exactly what this stream of new scientific knowledge will lead to, but past science and innovation continue to deliver new products into the market in collaboration with our commercial partners. Noteworthy were the launch in July of the first new raspberry variety for ten years, Glen Doll, developed from a cross that was originally made back in 1990, and the launch in October by Greenvale AP of the phureja potato Mayan Gold. The science underpinning the latter goes back many decades and involved genetics, physiology, agronomy and biochemistry in its development into a potential food; we shall follow the commercial development with interest.

One of the major strands of our science strategy is that we should seek to develop and strengthen appropriate partnerships and collaborative arrangements that will enable our mission to be carried out more effectively. I have spent quite a lot of my time trying to make that a reality at several levels. First, all of the directors of SEERAD's main research providers now meet regularly to discuss topics of mutual interest, and that is starting to lead to more coordinated approaches to policy matters. We are, for example, about to produce a brochure setting out the distinctive contribution that the Institutes make to Scotland and internationally. Second, SCRI is developing a network of links with universities throughout the UK through its new studentship programme that is broadening the skills base accessible to the Institute. Our partnership with the University of Dundee has been strengthened and extended beyond the plant sciences, and we shall be contributing research on plant mediated transfer of carbon to soils via the Scottish Alliance for Geosciences, Environment and Society. Third, SCRI is a partner with Rothamsted Research, the Institute of Grassland and Environmental Research, and the John Innes Centre in the BBSRC cross institute programme on cereal genetics, and is contributing some of its research activity on soils to a similar programme involving Rothamsted Research and the Institute of Grassland and Environmental Research. These programmes are important contributions to the UK science base and will strengthen our abilities to contribute internationally. Finally, during the year I visited the International Potato Center (CIP) in Peru and several institutions in China with which SCRI has been developing links. These international collaborations have much potential for development, but are already providing staff at SCRI with enlarged perspectives of the scope and applicability of their research endeavours.

I hope that you will enjoy reading about our year. I am very pleased to be leading such a dynamic group of people.

Review of events – Highlights

Communicating the results of their studies is a part of the research process taken very seriously by SCRI scientists. Throughout the year there were over 2,000 visitors including: school children; university students; clubs and societies; companies and people from around the world. Visitors came from other research institutes to understand more about the role SCRI plays in plant and environmental research, and special events were held to inform food producers, processors and retailers, and the general public about our work and its outcomes.

The major events this year were in partnership with other bodies. On May 23rd "Sustainable Agriculture – From Laboratory to Field" in collaboration with LEAF demonstrated research on farming and environment both in the field and in the laboratory.

Cereal Solutions in collaboration with SAC and HGCA showed farmers and cereal industry representatives how the understanding of genetic information is used to produce cereals for particular purposes such as varieties of wheat for distilling requiring reduced fertiliser. They also were guided round the HGCA Recommended List field trials at SCRI.

Fruit for the Future was a particular hit this year as the new cultivar Glen Doll was on display for tasting.

The blackcurrant project to track the production and storage of vitamin C in blackcurrant bushes and the fac-

tors that determine the levels of the nutrient in the fruit attracted ministerial interest.

Potatoes in Practice in collaboration with SAC, CSC PotatoCare and sponsored by the BPC was the most successful yet with over 600 visitors. It featured a display of Andean potatoes. Participants were able to sample baked Mayan Gold tubers. This new variety, bred at SCRI, was launched by Greenvale AP this year.

The stand at the Dundee Flower and Food Festival allowed people to test how much vitamin C can be found in different fruits. There were also games to identify wild plants.

Children are always a very important group of visitors, from Primary such as the group who came for Bring Your Child to Work day to the Higher biology and chemistry pupils.

The Governing Body said farewell to Professor Sir John Marsh CBE with a presentation and lunch. Sir John joined the governing body in April 1998 and served in many capacities including Vice-Chairman.

scri
living technology

Genetics

Robbie Waugh

In Genetics we conduct fundamental, hypothesis-led research supported by the development of biological resources and enabling technologies that underpin applied genetics research and product delivery. Over the last year we have begun the process of re-focussing our research programmes on some of the challenges raised by climate change, environmental concerns and the demand for healthy and nutritious food and feed. Thus we have realigned our research to encompass priorities that include tolerance to abiotic stress and lower input agriculture.

We fundamentally believe that a strong portfolio of basic research is necessary to fuel discovery and to develop the understanding required for innovation and future applications. However, a major aim is also to translate our research outcomes into approaches and technologies that enable genetic research in crops – particularly barley, potatoes and soft fruits – that underpin the Scottish agricultural sector. To enhance this process, we participate in national and international initiatives with academic and commercial partners to maintain the profile of our research and ensure its direct relevance to practical outcomes. We continue with active crop improvement programmes, working with industry to deliver products to the marketplace. Currently, Genetics contains approaching ninety staff, including three fully integrated research active groups from the University of Dundee (C. Halpin, A.J. Flavell and G.C. Simpson). A separate report from these groups follows. This brief overview contains research highlights from Genetics in 2006 that are not represented in the following, more detailed, scientific reports.

Over the last year we have extended our characterisation of the plant nucleolus, a major sub-nuclear organelle. The nucleolus is involved in a wide range of gene expression processes, but more recently it has been shown to act as a sensor of cellular stress in animal cells and to be involved in aspects of gene silencing in plants. With Peter Shaw at John Innes Centre (JIC), using a combined proteomics and RNomics approach, we have demonstrated a role for the nucleolus in mRNA export and degradation. In an entirely novel finding, we have demonstrated that some naturally-occurring antisense transcripts (NATs) are enriched in the nucleolus. NATs are likely to be involved in specific gene silencing and one of these has been shown to regulate gene expression in response to salt stress through the RNA interference pathway. The precise role the nucleolus plays in these processes remains a key question. More widely, many processes contribute to the overall regulation of gene expression during development and environmental challenge. Investigations into the role of alternative splicing are described by Craig Simpson and others in a following article.

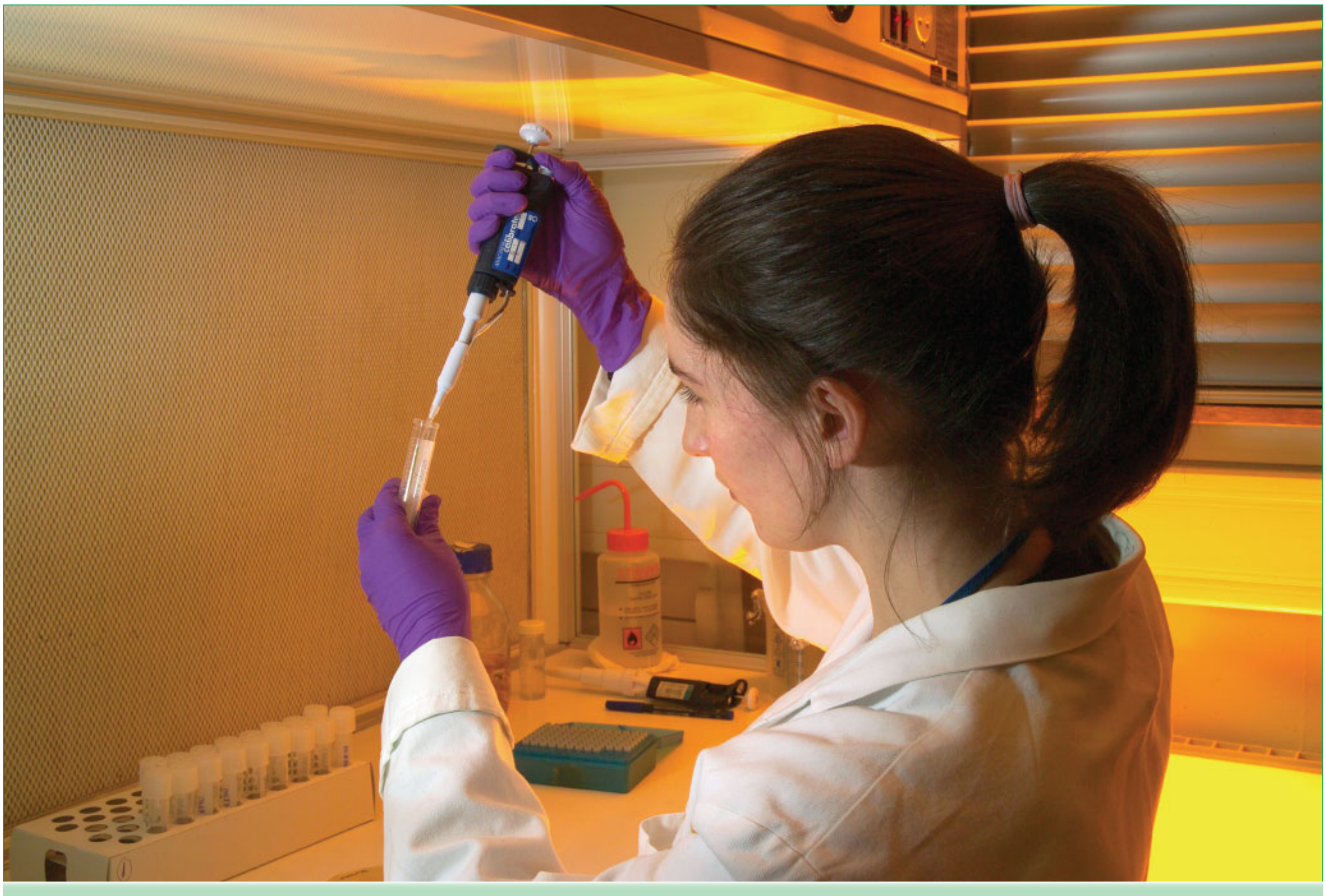
By exploring the genetic control of mRNA abundance in different plant genotypes we have been linking RNA-biology with genetics. We measured the abundance of more than 21,000 different barley mRNA species along with approximately 20 phenotypic traits in a segregating doubled haploid population. With Mike Kearsey in Birmingham University, we conducted linkage analysis, treating individual mRNA abundances as quantitative traits (QT) and identified thousands of genes showing highly heritable mRNA abundance levels. Hundreds of these are highly associated with phenotypic trait locations and a subset, strong regulatory and/or positional candidate genes, are under detailed investigation.

In all our studies, we consider it crucial that we correlate molecular data with classical phenotypic traits. In a collaboration with NIAB, analysis of multiple small barley mapping populations has highlighted the dependence of characters such as fermentability upon wort sugars (principally maltose) and revealed the close relationships between the activity levels of enzymes in the malting process that are regulated by the plant hormone gibberellic acid. With Jose-Luis Molino-Cano in Lleida, Spain, we identified three QT loci for grain β-glucan content. This is directly relevant to malting quality as low levels of β-glucan, a major component of barley endosperm cell walls, are important in the brewing and distilling industries. The largest QT locus co-locates with the hulless (naked) gene. As hulless barley is generally high in β-glucan, a compound with proven cholesterol-reducing effects, this linkage could be exploited through breeding to generate barleys tailored for human nutrition. In future, many more such linkages will be identified in a UK-wide collaboration using the approach described by Luke Ramsay and others in a following article.

Our studies in barley are possible because of its well developed genetics. However, last year, we also produced the first genetic linkage map of blackcurrant (*Ribes nigrum* L.) and screened many important phenological, agronomic and fruit quality traits in the mapping population. This is described further in the article by Rex Brennan and others which follows. In raspberry, we have previously shown that Gene H is associated with resistance to cane botrytis and spur blight, but not with cane spot and yellow rust. Markers have been identified linked to the four diseases. Gene H has been mapped and is now the focus of a positional cloning effort. Importantly, in July this year we released a new raspberry cultivar, Glen Doll, our first in 10 years.

Exploiting biodiversity has underpinned the development of new SCRI cultivars. Last year we extended our molecular analysis of the Commonwealth Potato Collection (CPC) to describe diversity in wild and cultivated species from different geographic origins, ploidy and breeding systems. We confirmed that there is considerably less genetic diversity among accessions of self-compatible as compared to self-incompatible taxa. However, diversity among individuals drawn from different accessions was of similar magnitude in self-compatible and self-incompatible species, with the former showing only slightly lower rates of polymorphism. The most diverse accessions were the cultivated potato accessions, and the least, the Mexican polyploids. Thus, for diversity and phylogenetic studies, a single plant is highly representative of inbreeding or moderately outbreeding accessions while for highly heterozygous self-incompatible species, a deeper sampling of more individuals is advisable. These observations have significant implications for the *ex situ* maintenance of *Solanum* germplasm in genebanks such as the Commonwealth Potato Collection (CPC) held at SCRI.

Testament to the potential benefits of exploiting biodiversity, the launch of the new SCRI-bred cultivar Mayan Gold (*Solanum tuberosum* Group Phureja, also known as *S. phureja*) by Greenvale AP, made the UK National



News. It is the first potato from this group to be commercialised outside of South America and is derived from the diploid cultivated potatoes of Venezuela, Colombia, Ecuador, Peru and Bolivia. It has an interesting flavour and makes excellent French fries and roast potatoes. Greenvale AP have also successfully established Vales Emerald as an early punnet type and Vales Sovereign for prepack. Lady Balfour now commands approximately 40% of organic maincrop production. It has field resistance to late blight derived from the Mexican wild species *S. demissum* and partial resistance to cyst nematodes derived from the South American wild species *S. vernei.* Vales Everest has the best resistance to the white potato cyst nematode, *Globodera pallida*, of any cultivar on the UK National List. Its resistance is derived from an Andigena potato accession in the CPC.

Genetics manages two Institute-wide research facilities. First, the Sequencing Service provides a complete 'DNA template to data' pipeline in a highly efficient and cost-effective manner that is widely used by all Programmes across the Institute. Second, the Microarray facility completed numerous collaborative projects including key publications on an analysis of dormancy control in *Rubus* and pathogenicity studies in *Erwinia*.

Finally the changes in Institute status have reinforced the need for each Programme to win competitive research funding from a diverse range of sponsors. Last year we secured major new funding from the Crop Science Initiative, ERA-PG, Generation Challenge programme, EU-Sol, IAEA and EU-FP6. These successes are firmly based in the quality and competitiveness of our science. They will enhance our research and development portfolio and help us remain agile in an increasingly competitive research environment.

Alternative splicing and plant stress

Craig G. Simpson, John Fuller, Jim McNicol, Diane Davidson & John W.S. Brown

Alternative splicing (AS) modulates gene expression during development and in response to external stimuli. When a gene is transcribed, introns are removed by splicing at the splice sites bordering the intron. Around a third of plant genes show alternative selection of splice sites leading to the production of more than one mRNA from the same gene by alternative splicing (Fig. 1A). The different AS transcripts can give rise to proteins with altered function or activity which affect the cell's characteristics. Therefore AS effectively expands the information content of the genome through increasing protein diversity allowing the plant to rapidly respond to immediate changes in conditions and providing one basis for selection for adaptation during evolution.

The importance of AS is well illustrated in humans where mutations in splice sites or regulatory splicing factors affect AS with profound effects contributing to diseases such as muscular dystrophy, Parkinson's disease and cancer. In plants, the involvement of AS in regulating plant phenotypes and responses is reflected in the many examples of AS in genes involved in development, disease and stress responses as well as in transcription and RNA-interacting factors. For example, resistance to *Tobacco mosaic virus* and the "sticky" rice phenotype are both due to alternative splicing.

AS is also a key area where gene expression is regulated. It is controlled by the composition of multiple protein factors (such as SR or hnRNP proteins) and their interaction with sequences on gene transcripts. The relative levels or activity of these proteins change in different cells or conditions through transcription, protein modification or localisation, so the alternative splicing pattern of sets of genes is altered and different proteins with different activities are produced (Fig. 1B). For example, different hormones such as ABA and stress conditions can activate phosphorylation signalling pathways which will alter the phosphorylation state of splicing regulators, affecting AS of downstream target genes. Thus, the characteristics of different cell types, cells at different stages of development or in response to external stimuli are dependent on the cellular code of

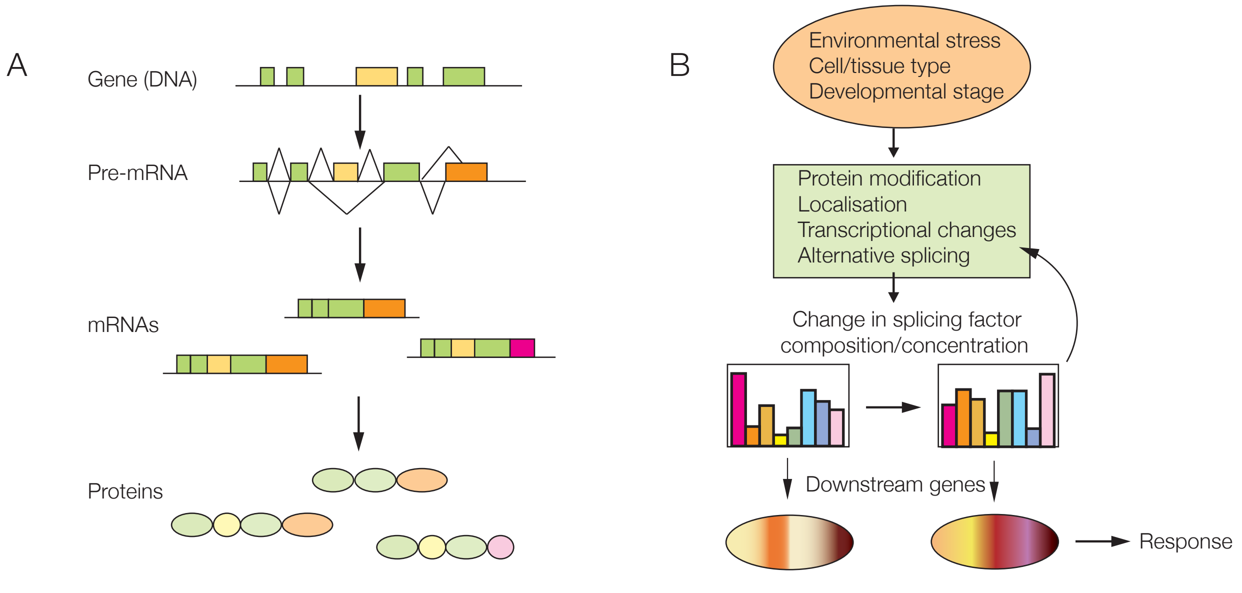
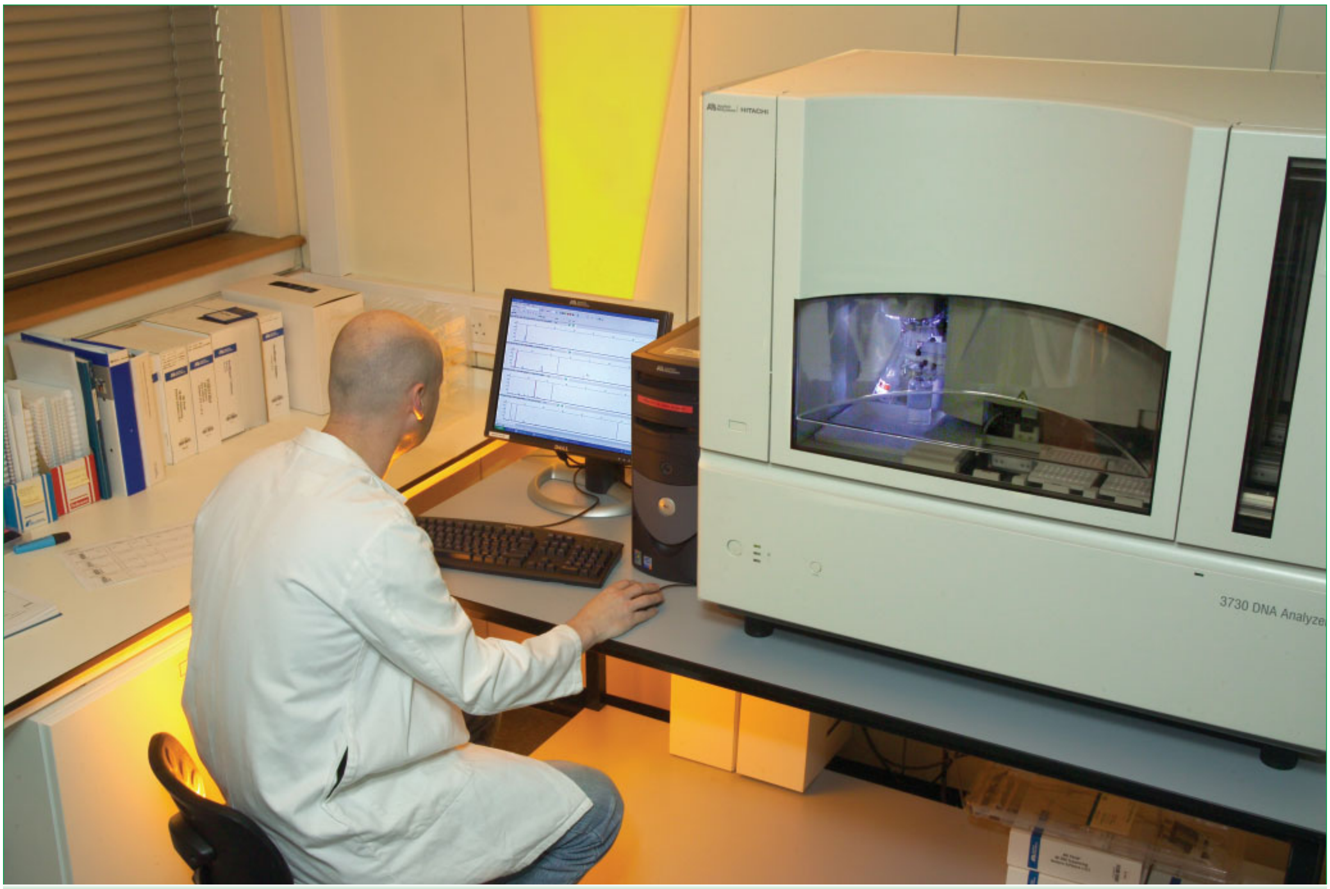


Figure 1 A) Genes are transcribed into precursor mRNAs which through AS give rise to different mRNAs and proteins with different functions. B) Developmental cues and external stimuli cause changes in transcription and alternative splicing resulting in altered splicing factor concentrations which further affect expression of downstream genes to alter the cell's growth or response properties.



regulatory factors which determine transcriptional and alternative splicing activity.

The challenges are to identify AS events, determine the functional consequences, and decipher the cellular code of regulatory proteins and signalling pathways responsible for altering AS patterns of target genes. As a first step, we have successfully developed a system to analyse AS in around 100 genes simultaneously. More than one third of the genes analysed show statistically significant changes in AS under different growth conditions and in different plant organs. Expansion of this system to cover a few hundred genes specifically involved in transcription, splicing and signalling in *Arabidopsis* and barley will allow us to investigate changes in AS in response to biotic and abiotic stresses, different growth conditions and developmental stages, and to link these changes with changes in transcription levels. This research is partially supported by a European Network of Excellence on AS and human disease (EURASNET) where 35 laboratories from 13 countries are analysing AS in yeast, plants, animals and humans to generate new knowledge of the mechanisms of AS regulation as a prerequisite to understanding a range of diseases and developing treatments.

A genetic linkage map of blackcurrant (*Ribes nigrum* L.)

Rex M. Brennan, Linzi Jorgensen, Christine A. Hackett, Mary Woodhead, Sandra Gordon & Joanne Russell

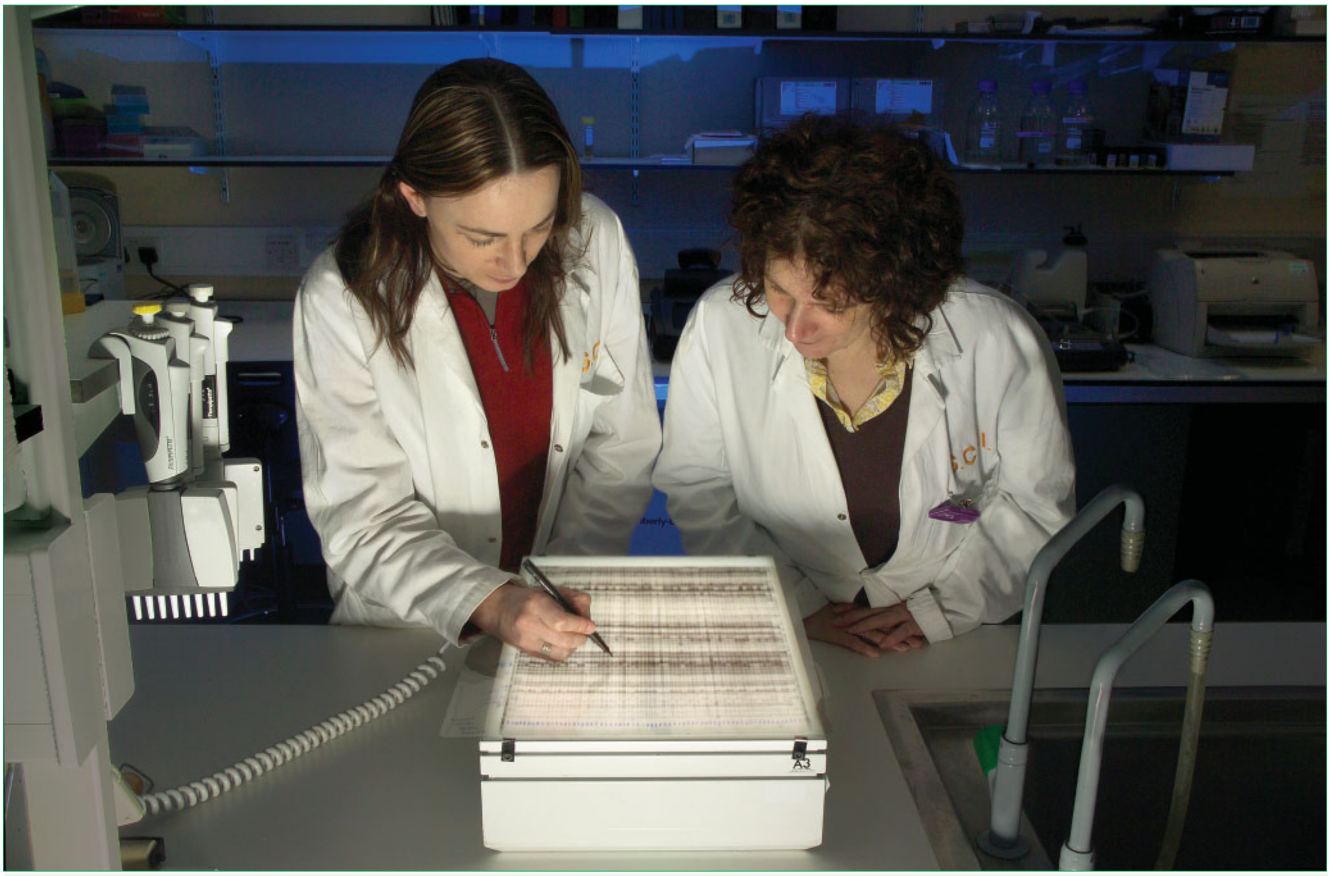
Breeding of new blackcurrant cultivars is generally protracted, partly due to the heterozygous nature of the germplasm involved and also to the fact that effective screening of breeding germplasm for many of the most important traits, such as gall mite resistance, can take several years to complete. As a consequence, there is considerable potential utility for marker-assisted breeding and earlier identification of desirable phenotypes in *Ribes*. There are also breeding objectives of increasing the levels of both ascorbic acid and anthocyanins within the breeding germplasm and ultimately in new cultivars for the industry, in order to enhance the nutritional value of the fruit. Developmental traits, such as time of budbreak, are also important, as the effects of increasingly mild winters on dormancy break of blackcurrant are already a matter of concern (Atkinson *et al*., 2005).

The development and potential use of molecular markers in *Ribes* has been previously reported (e.g. Brennan *et al*., 2002), and now the first genetic linkage map of blackcurrant (*Ribes nigrum* L.) has been constructed using Amplified Fragment Length Polymorphism (AFLP), Simple Sequence Repeat (SSR), both genomic and expressed sequence tag (EST)-derived, and single nucleotide polymorphism (SNP) markers. The population used, designated 9328, comprises a F_1 full-sib progeny from a cross between two diverse breeding lines from SCRI. The parental types were selected for their diversity across a range of agronomic, developmental and fruit quality traits; these included resistance to gall mite, berry size, time of budbreak and flowering, anthocyanin content and ascorbic acid level, all of which are key traits in the SCRI blackcurrant breeding programme. The offspring were scored for these traits in a three-year field trial.


SCRI-bred blackcurrant cv. `Ben Starav'

Cluster analysis of the marker data from this population revealed that the individuals formed two distinct sub-populations, with segregation ratios consistent with one sub-population having the two intended parents, and the other being selfed segregants. The latter sub-population provided useful additional information that improved the construction of the genetic linkage map: it provided a more informative estimate of recombination frequency than the crossed sub-population for some marker configurations, and also revealed the presence of two unlinked loci affecting viability, whose positions could be mapped approximately.

Quantitative trait locus (QTL) interval mapping was used to identify locations on the marker map that are associated with variation in the trait data. A single gene for gall mite resistance was mapped to linkage group 2. A total of five QTLs for developmental traits (bud break, first leaf, first flower and full flower) were identified. Three QTLs for pH were found, and two for ascorbic acid, one



Analysing mapping data

of which was close to the gene for gall mite resistance. Three QTLs for berry size were also found, two of which were close to the loci affecting viability in the selfed segregants.

This analysis provides a framework for the development of marker-assisted breeding strategies for blackcurrant, to improve breeding efficiency and time to cultivar. Further analysis, particularly of the quantitative traits, will require a larger mapping population, and this is currently in progress at SCRI with an extension of the 9328 population to 300 individuals. Additionally, markers located close to the map position for gall mite resistance are currently undergoing validation across a range of diverse germplasm, with initial indications very promising in terms of a robust marker with utility within the SCRI blackcurrant breeding programme.

References

Atkinson, C., Sunley, R., Jones, H.G., Brennan, R.M. & Darby, P. 2005. Defra desk study on winter chill in fruit. *Defra Report* **No. CTC 0206**.

Brennan, R.M., Jorgensen, L., Woodhead, M. & Russell, J. 2002. Development and characterisation of SSR markers in *Ribes* sp. *Molecular Ecology Notes* **2,** 327-330.

Breeding facilitates whole genome LD-mapping

Luke Ramsay, Nils Rostoks, David Marshall, Sharon Mudie, Timothy J. Close & Robbie Waugh

In plants, mapping traits and isolating the underlying genes has largely been based on following the inheritance of molecular markers in specific experimental populations derived from crosses between two parents that contrast for the trait under study. However, a more general population-based approach termed 'association genetics', or 'linkage disequilibrium (LD) mapping' (based on the non-random association of alleles in a population), is now being routinely used to map disease genes in humans. In crop plants, the potential of association mapping, with the objective of estimating the position of genes conferring a specific trait by exploiting LD between alleles of genetically mapped markers, has become a focus of considerable interest. A major attraction of LD-mapping is the potential to locate genes responsible for a wide range of traits in a sample population using pre-existing trait data collected during crop improvement and cultivar registration programmes. However, to be successful, the extent of LD must be known in the gene pool under study, and based on this, an appropriate number of molecular markers assembled into a format suitable for high throughput genotypic analysis.

Over the last several years we have directly assessed both the extent of LD, and the patterns of genetic diversity within elite cultivated barley (Fig. 1). Our observations allow us to predict that around one polymorphic marker per centi-Morgan (cM) will be necessary for whole genome LD-scans. Over the same period we also set out to develop a genotyping platform that would simplify genetic analyses in barley and facilitate the LD-mapping approach. Using expressed sequence tags (ESTs) as a template, we identified 1524 barley single nucleotide polymorphisms (SNPs) and used them to produce a pilot oligonucleotide pool array (OPA) for use with 'Illumina' GoldenGate Bead-Array technology (a gel-free parallel genotyping technology developed alongside the human genome sequencing and HapMap projects). We used the pilot OPA to genotype three bi-parental doubled haploid mapping populations and 102 barley cultivars. 91% of the SNP assays were successful, confirming the utility of the technology for high throughput genotypic analysis in barley. 1029 of the 1391 polymorphic SNPs segregated in at least one of the three populations with over 240 in any two cross comparisons and 146 in all three. We constructed linkage maps of each population and then developed a high quality integrated map comprising all 1029 SNPs.

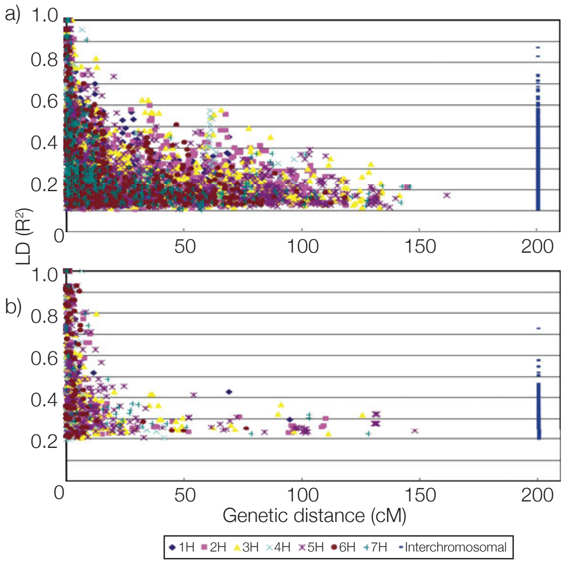
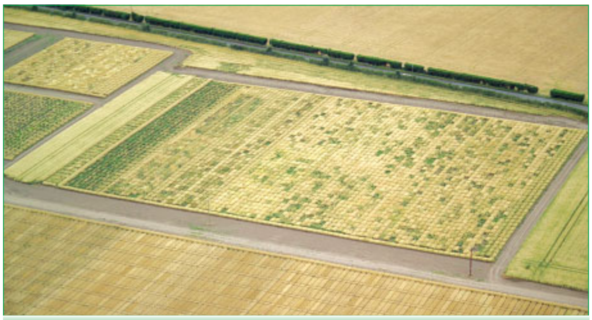


Figure 1 Plots of LD against genetic distance for all European barley lines (a) and spring varieties (b)



We then used the SNP data from the 102 genotypes to study genetic diversity, population structure and the extent of LD. We observed three major subgroups within the germplasm, European spring and winter

material (n=91) and more exotic lines. Highly significant intra-chromosomal LD ($p>0.001$, $r^2>0.5$) extended over more than 60 cM (mean 3.9 cM, median 1.16 cM) in the combined European barley set. 20.4% of all significant ($p>0.001$) associations ($r^2>0.05$) were inter-chromosomal, demonstrating the impact of population sub-structure. In the spring 2-row subset (n=53), LD extended only up to 15 cM (mean 1.53 cM, median 0.8 cM) and the proportion of inter-chromosomal associations was reduced to 2%. To test whether we could use LD to locate genes we examined whether we could correctly position any of the 362 unmapped genes in our pilot OPA dataset via an LD-mapping approach. We calculated pair-wise LD (r^2) for each of the unmapped and mapped loci and assumed that strong LD indicated linkage. We were able to assign a putative map location to over 50% of the unmapped loci. Theoretical predictions suggest that LD in barley, an inbreeder, should persist over very long distances and generate many false positives in LD-mapping studies. However, we show that LD has broken down sufficiently in elite cultivated lines, probably due to repeated crossing by breeders, to allow LD-mapping to be carried out successfully.

scri
living technology

Plant Pathology

Lesley Torrance

Plant pathology research provides underpinning knowledge to support sustainable agricultural production systems. We aim to understand, using molecular, cellular and whole plant techniques, mechanisms of plant resistance and susceptibility and discover how parasites evolve to overcome plant defences. Our applied science to detect pests and pathogens and to monitor and to predict changes in pathogen populations is conducted in collaboration with agencies or growers.

Advances in genome sequencing (pathogen and plant) combined with bioinformatics analysis and functional genomics techniques are being exploited to accelerate the discovery and characterisation of novel genes and processes. This year, research on *Pectobacterium atrosepticum* has shown the power of these approaches with the discovery of novel systems to enable this bacterium to survive in the absence of potato in managed ecosystems. This work has deepened our understanding of quorum sensing. With the first draft of the *Phytophthora infestans* genome now available, we anticipate similar strides to be made with this severe potato pest and substantial funding from EU and BBSRC has been won to pursue this. Research on plant viruses has revealed new insights into the importance of nuclear trafficking in virus replication and movement.

Climate change is of considerable worldwide concern and this year we have produced a report that identifies potential changes in disease profiles in Scottish crops, particularly the threat posed by pests and diseases whose spread is currently limited by the cooler temperatures of Northern Britain. This study will influence the direction of future programme research. New developments also include collaborations with colleagues in EPI programme on the survival and spread of soil-borne microorganisms in the environment.

More detail of our research can be found on the Plant Pathology Programme's pages on the SCRI website.

Research highlights include:

Demonstration of a role for plant ALY proteins in RNA silencing RNA silencing is a defence mechanism that targets RNAs of invading pathogens for destruction. Two of the four plant nuclear protein ALYs become localised in the cytoplasm when the cell is infected with *Tomato bushy stunt virus* (TBSV) or when only the P19 protein is expressed, suggesting that plant ALY proteins are involved in the RNA silencing process.

Enhanced resistance to viruses by manipulation of disease-response genes It seems that while the HCPro gene is able to suppress the RNA silencing-mediated defence against virus infection, it stimulates other anti-viral defence systems. So, broad defence against a range of plant viruses could be achieved by down-regulating the expression of defence genes. The RDR1 gene from potato has been cloned and sequenced and its role in regulating virus infection in potato is being assessed.

Involvement of sub-nuclear bodies in plant virus systemic infection (See following article by Sang Hyon Kim *et al*.)

New insights into *Potato mop-top virus* (PMTV) movement Recent co-localisation experiments with fluorescent-tagged plant endosomal markers show that movement proteins localise in patches at the plasma membrane and associate with endosomes. Cell-to-cell movement of infectious virus particles requires movement proteins. Endocytic trafficking may be important in the uptake and delivery of virus by its soil–borne vector, *Spongospora subterranea*.

Targeting of *Tobacco mosaic virus* movement protein to plasmodesmata requires the actin / ER network Although movement protein is frequently seen associated with microtubules it has been shown that the microtubules are not required for targeting to the plasmodesmata.

New golgin protein identified An eighth possible *Arabidopsis* golgin, a homologue of the mammalian Golgi protein p115, localises to Golgi stacks and interacts with *Arabidopsis* Rab1 homologues in a yeast two-hybrid assay.

AtGRIP accumulates in the *trans*-Golgi network Using immuno-gold labelling and electron microscopy, the localisation of three novel *Arabidopsis* golgin candidates has been analysed in detail.

Progress in understanding how some strains of *Raspberry bushy dwarf virus* (RBDV) overcome resistance Some RBDV isolates capable of overcoming the resistance provided by the *Bu* gene carried by some raspberry cultivars have been found in England and elsewhere. SCRI's ability to infect raspberry plants with cloned infectious non-resistance breaking RBDV will form the basis of a rapid and efficient procedure to screen new germplasm for additional sources of resistance to the virus.

VirD2 protein mutants increase efficiency of gene transfer The VirD2 protein has been shown to be a substrate for a plant caspase-like protease activity (PCLP) in tobacco. It has been demonstrated that mutagenesis of the VirD2 protein to prevent cleavage by PCLP increases the efficiency of reporter gene transfer and expression.

Release of a first assembly of the *P. infestans* genome sequence SCRI are involved in the genome project through supply of our large insert BAC library. The sequencing effort is led by the Broad Institute, Cambridge, MA, USA (www.broad.mit.edu/annotation/genome/phytophthora_infestans/Home.html).

Functional genomic analyses of *P. infestans* genes We have identified a novel transmembrane protein that is localised to the appressoria and haustorial membrane. Appressoria are preinfection host penetration structures, and haustoria are biotrophic structures formed early in infection and likely to be used in nutrient extraction from the host. Silencing of this gene decreased *P. infestans* pathogenicity.

P. infestans effector protein *Avr*3a transport into host cells depends on a conserved RXLR-EER motif (See following article by Stephen Whisson *et al.*).

P. infestans populations There is concern about the potential for increased incidence of the sexual oospore stage of the late blight pathogen. Genetic analysis using markers is providing key data to explain how the population and the nature of the primary inoculum is changing. This data feeds into the BPC's Fight Against Blight Campaign and a longer-term study on how pathogen populations evolve, research on the mechanisms of *P. infestans* pathogenicity and breeding for blight resistance.

The first phytotoxin and its mode of regulation have been identified in *Pectobacterium atrosepticum* *P. atrosepticum* (formerly known as *Erwinia carotovora* subsp. *atroseptica*) attacks plants through the production of large quantities of plant cell wall degrading enzymes via a cell density dependent regulatory process called quorum sensing. We have recently shown that a phytotoxic compound called coronafacic acid is required for virulence on potato and its mode of action appears to be in suppressing host resistance.

Disease risk assessment for soil-borne potato diseases (see following article by Alison K. Lees *et al.*).

RanBPM gene family identified in nematodes Expression analysis has shown that all family members (encoding proteins similar to RanBPMs) examined to date are expressed in the dorsal oesophageal gland cell of *Globodera pallida*, suggesting a role for these proteins in the host-parasite interaction.

Chorismate mutase (CM) plays key role in nematode infection Studies on a secreted chorismate mutase using RNA interference, a mechanism for RNA-guided gene silencing, have revealed that this protein is important for normal development of the nematode. The most significant effect is on adult females, which have the greatest nutritional requirements, suggesting the CM is important in inducing or allowing normal establishment of the feeding site.

Production of a cDNA library from a parasitic stage of *G. pallida* Nematodes from various stages of infection from potato roots were isolated and high quality RNA extracted to make a representative cDNA library. Preliminary analysis has revealed the presence of candidate pathogenicity and avirulence genes.

Quantitative molecular diagnostics (QMD) for nematodes QMD have been developed for the potato cyst nematodes *G. pallida* and *G. rostochiensis.* QMD have also been produced for the virus vector nematodes *Paratrichodorus pachydermus* and *Trichodorus similis* and the virus associated with these species, *Tobacco rattle virus*. These tests were devised for use in a pre-planting soil test with funding from the British Potato Council.

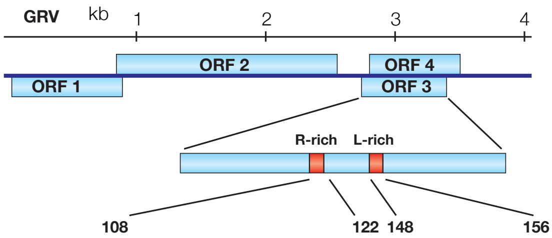
Rapid method for DNA analysis of suction trap aphids SCRI is one of four suction trap sites in Scotland (see www.sasa.gov.uk/seed_potatoes/aphids/index.cfm). These traps sample migrant flying aphids. The numbers and types of each species caught in the traps are used to formulate advice to farmers on the frequency of pesticide applications. We have developed a rapid method for extracting DNA from current and historical trap samples so that DNA fingerprinting can be used to identify subtypes and insecticide-resistant forms.

Nuclear voyage of a plant virus protein

Sang Hyon Kim, Eugene V. Ryabov, Trudi Gillespie, Stuart MacFarlane, Sophie Haupt, John W.S. Brown & Michael Taliansky

The nucleolus is a prominent sub-nuclear domain and is the site of transcription and processing of pre-rRNAs and biogenesis of pre-ribosomal particles. In addition, the nucleolus participates in other aspects of cell function such as stress responses and the cell cycle. The nucleolus is structurally and functionally linked to Cajal bodies (CBs) that contain small nuclear and small nucleolar ribonucleoprotein particles (snRNPs and snoRNPs) as well as a range of different proteins, including nucleolar protein fibrillarin. CBs are dynamic structures which can move within the nucleus. The multifunctional nature of the nucleolus and CBs has recently been extended to include RNA silencing; the production of heterochromatic small interfering RNAs involved in transcriptional silencing occurs in CBs or other processing foci in the nucleolus. A number of animal and plant viruses have a nucleolar phase in their life cycles. However, the specific role of the nucleolus and other sub-nuclear bodies in virus infections has remained elusive.

Our recent work has provided the first model describing the molecular mechanism of the involvement of sub-nuclear bodies, CBs and the nucleolus, in biological functions of a plant virus. We have shown that the ability of *Groundnut rosette virus* (GRV) to move long-distances through the phloem strictly depends on its interaction with CBs and the nucleolus. Umbraviruses differ from most other viruses in that they do not encode a capsid protein (CP) such that conventional virus particles are not formed in infected plants. The absence of a CP in umbraviruses, however, is compensated for by the ORF3 protein that facilitates long-distance movement of viral RNA in the form of viral RNP particles through the phloem, the specialised vascular system used by plants for the transport of assimilates and macromolecules. After entering the plant cell, GRV establishes translation and replication of viral RNA (Fig. 1). Once the ORF3 protein has been translated it enters the nucleus and targets Cajal bodies (Fig. 2). Targeting of CBs by the ORF3 protein may utilise elements of existing CB-trafficking pathways, for example, those used by snRNPs trafficking from the cytoplasm to CBs. Interaction of the ORF3 protein with CBs further leads to the re-organisation of CBs into multiple Cajal body-like structures (CBLs), which may involve either fragmentation of CBs into multiple bodies or the redistribution of CB components into new structures containing the ORF3 protein. In CBLs the ORF3 protein interacts with fibrillarin. This interaction prompts further CBLs movement to and fusion with the



ORF3(WT)	RPRRRAGRSGGMDPR	LLPSLLNTL
RA	***A***P***AAA***AG***A***SGGMDP***A***	LLPSLLNTL
LA	RPRRRAGRSGGMDPR	***AA***PS***AA***NT***A***
L149A	RPRRRAGRSGGMDPR	L***A***PSLLNTL
L152A	RPRRRAGRSGGMDPR	LLPS***A***LNTL
L153A	RPRRRAGRSGGMDPR	LLPSL***A***NTL

Figure 1 GRV ORF3 protein domains involved in nuclear localisation. Schematic representation of the GRV genome with wild-type and mutant ORF3 protein sequences of the R-rich and L–rich domains.

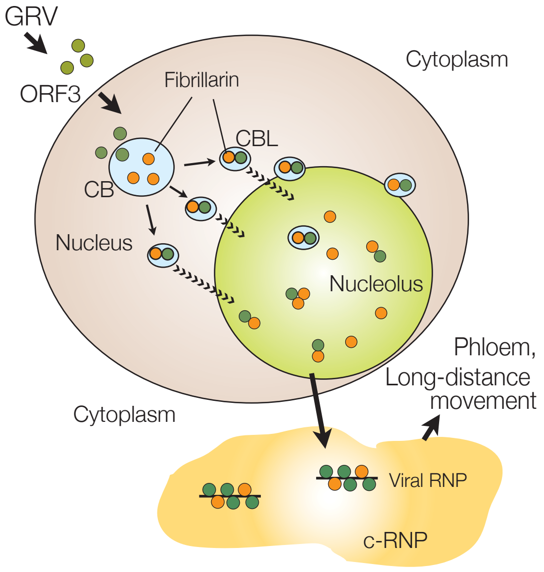


Figure 2 Model of GRV infection and the role of the ORF3 protein, fibrillarin, Cajal bodies and the nucleolus.

nucleolus. The last stage of the nuclear voyage of the ORF3 protein is its nuclear export leading to formation of virus RNP particles in cytoplasmic inclusions. During this stage the ORF3 protein causes the re-localisation of some of the fibrillarin pool to the cytoplasm where viral RNPs containing ORF3 protein, fibrillarin and viral RNA accumulate. Fibrillarin, an RNA-binding protein, needed for RNP formation, may bind the viral RNA or act as a chaperone to permit or catalyze the regular assembly of proteins around viral RNA. When produced in companion cells, the viral RNPs are able to migrate into the phloem sieve elements where they are transported to the rest of the plant to generate a systemic infection.

Thus the interaction of the GRV ORF3 protein with fibrillarin triggers all the consequent molecular and cellular events to establish a systemic infection. How the ORF3 protein re-programmes trafficking pathways and molecular interactions for successful infection will have implications for other plant viruses which interact with the nucleolus and will aid our understanding of interactions between the nucleolus, CBs and their components.

Effector protein translocation in the *Phytophthora infestans* – potato infection

Stephen C. Whisson, Petra C. Boevink, Leighton Pritchard, Anna O. Avrova, Juan G. Morales, Paul R.J. Birch

Disease of plants caused by oomycetes are among the leading causes of crop loss and ecosystem damage worldwide. This is exemplified by the late blight pathogen of potato, *Phytophthora infestans*, which is best known for its role in precipitating the Irish potato famines in the mid-1840s. Today, late blight is still a significant problem in potato production and is considered a threat to global food security; resistance and chemical control can be overcome by pathogen variants. The mechanisms underlying how *P. infestans* invades its hosts, and how resistance is triggered have been significantly advanced in recent years. A major advance in the understanding of *P. infestans*–potato interactions came with the isolation, at SCRI, of the first avirulence gene (*Avr*3a) from this pathogen (Armstrong *et al.,* 2005); the protein products of avirulence genes are recognised and trigger resistance responses in plants carrying the cognate resistance gene. *Avr*3a shares a similar organisation with the other three oomycete avirulence genes identified to date (Rehmany *et al.,* 2005): an N terminal signal peptide for secretion, peptide motifs of RxLR and EER within the first 70 amino acids, followed by the portion of the protein that is recognised by the matching

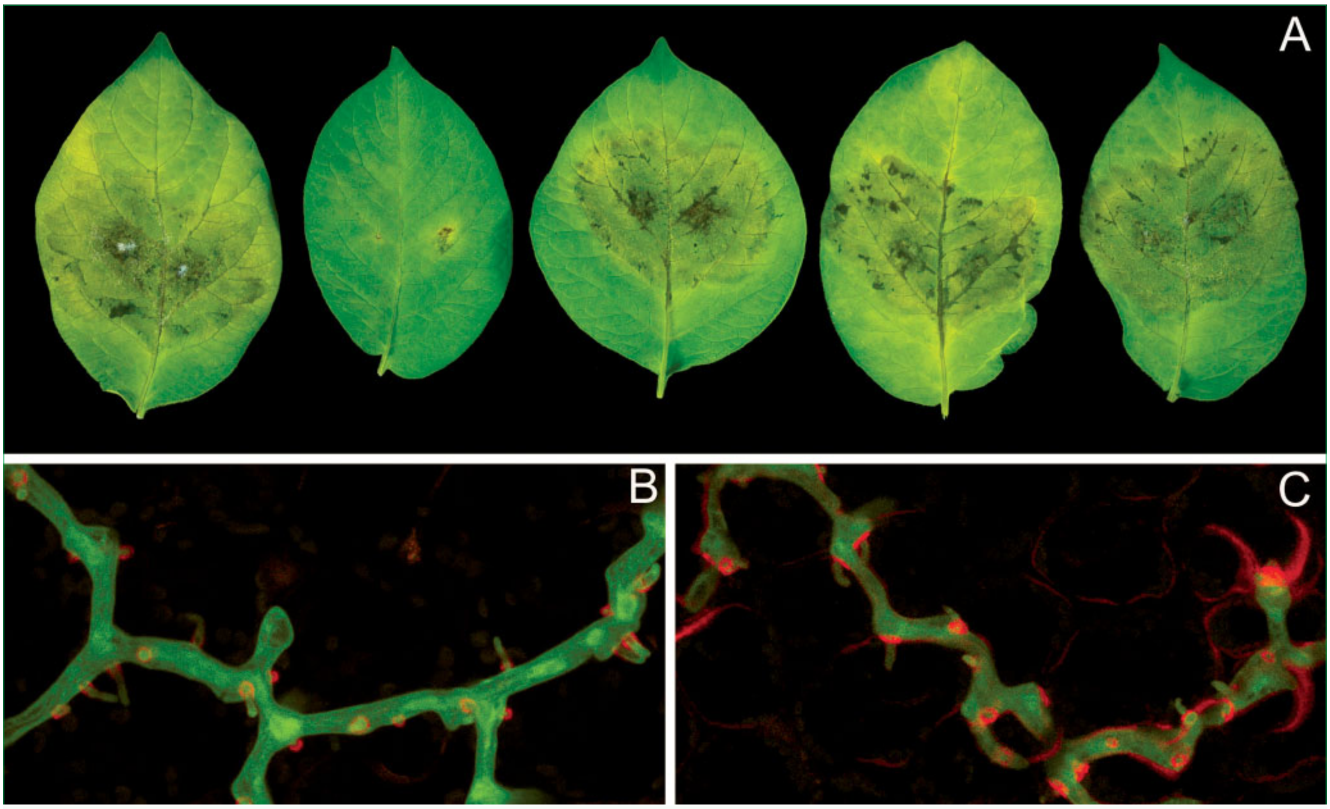


Figure 1 (A) Potato cultivar Pentland Ace (*R3a*) leaves infected with (from L – R): untransformed *P. infestans* expressing the virulent allele of *avr*3a, transformant expressing native avirulent allele *Avr*3a with intact RxLR-EER, transformant expressing alanine replacement of *Avr*3a (AAAA-EER), transformant expressing alanine replacement of *Avr*3a (RxLR-AAA), transformant expressing alanine replacement of *Avr*3a (AAAA-AAA). Transformants were all fully pathogenic on potato cultivars lacking late blight resistance genes. (B) Confocal microscopy image of a *P. infestans* transformant expressing a native AVR3a::mRFP fusion during infection of potato, showing AVR3a secretion (red fluorescence) only from finger-like haustoria. (C) As in B but with the RxLR-EER of AVR3a replaced by alanine amino acids; the red fluorescence is no longer restricted to the haustoria.

resistance protein in the host plant. The function of the RxLR-EER motifs has been speculated to be functionally similar to the host targeting signal (RxLxE/Q) in secreted proteins of malaria parasites (Haldar *et al.,* 2006). The role of these dual motifs in translocating secreted proteins of *P. infestans* was recently demonstrated at SCRI (Fig. 1A). AVR3a is only recognised inside potato cells that express the R3a protein and the RxLR-EER is not required for the recognition process. The RxLR and EER motifs were replaced by alanine amino acids in the AVR3a protein. This experiment demonstrated that both the RxLR and EER motifs are required for transport of the AVR3a protein, as AVR3a was no longer recognised in R3a cells. The role of these dual motifs was further investigated by translational fusion of the native and alanine replacement *Avr*3a genes to the monomeric red fluorescent protein, followed by confocal microscopy (Fig. 1B). This showed that AVR3a is secreted from *P. infestans* haustoria, which are finger-like biotrophic structures that are invaginated into plant cells and are therefore in intimate contact with host cytoplasm. In comparing the cellular localisation of different forms of AVR3a fused to mRFP, the alanine replacement version was intensely fluorescent surrounding the haustoria, and red fluorescence was observed in the plant intercellular spaces, as if accumulating and overspilling the extra-haustorial matrix (Fig. 1C). This is also consistent with a role for the RxLR-EER motifs in protein translocation across host plant membranes.

A bioinformatics search of the *P. infestans* genome sequence, plus 18,000 unique gene sequences, yielded a prediction of 425 RxLR-EER class genes for *P. infestans*. A subset of these, derived from unigenes, showed that all were up-regulated either in preinfection stages or during infection, consistent with the hypothesis that the encoded proteins are involved in establishing and maintaining host plant infection. Screening of these genes using a transient gene silencing strategy developed at SCRI has revealed that some play a role in establishing infection. The central role that the RxLR-EER motifs apparently play in translocating *P. infestans* effectors into plant cells, provides potential targets for novel oomycete disease control strategies.

References

Armstrong, M.R., Whisson, S.C., Pritchard, L., Bos, J.I.B, Venter, E., Avrova, A.O., Rehmany, A.P., Böhme, U., Brooks, K., Cherevach, I., Hamlin, N., White, B., Fraser, A., Lord, A., Quail, M.A., Churcher, C., Hall, N., Berriman, M., Huang, S., Kamoun, S., Beynon, J.L. & Birch, P.R.J. 2005. An ancestral oomycete locus contains late blight avirulence gene *Avr*3a, encoding a protein that is recognized in the host cytoplasm. *Proceedings of the National Academy of Sciences, USA* **102**, 7766-7771.

Haldar, K., Kamoun, S., Hiller, N.L., Bhattacharje, S. & van Ooij, C. 2006. Common infection strategies of pathogenic eukaryotes. *Nature Reviews Microbiology* **4**, 922-931.

Rehmany, A.P., Gordon, A., Rose, L.E., Allen, R.L., Armstrong, M.R., Whisson, S.C., Kamoun, S., Tyler, B.M., Birch, P.R.J. & Beynon, J.L. 2005. Differential recognition of highly divergent downy mildew avirulence gene alleles by *RPP1* resistance genes from two *Arabidopsis* lines. *Plant Cell* **17**, 1839-1850.

Molecular diagnostics: quantitative tools for investigating potato pathogens

Alison K. Lees, Jennie L. Brierley, Jenny A. Stewart, Louise Sullivan & Danny W. Cullen

Potatoes are subject to attack from a wide range of seed- and soil-borne pathogens. In order to develop effective strategies for minimising disease risk in potato production, it is first necessary to understand the factors governing the incidence and severity of diseases caused by these pathogens: for example, the method of transmission of the pathogen, the relative importance of different sources of inoculum and factors influencing infection and the subsequent development of disease symptoms.

Current knowledge of the epidemiology of individual potato diseases varies according to both their historical and perceived importance and also to ongoing changes in the pathogen population such as increased levels of fungicide resistance, or selection for pathogenic strains. There are many remaining epidemiological questions and work has, in some cases, been hindered by the inability to detect the pathogen at an early, or symptomless, stage of host infection. Accurate quantification of the pathogens on tubers, by methods other than visual assessment, which can be subjective, and also in soil is important. At SCRI, the development of reliable, specific, real-time PCR assays for the detection and quantification of potato pathogens (Table 1) has provided the tools needed to investigate these questions and new studies have therefore been instigated.


Potato showing symptoms of a range of blemish diseases.

By using the PCR based quantitative diagnostic assays in combination with conventional measurements of infection and disease symptom expression, BPC and SEERAD funded work has allowed us to accurately measure the effect of soil inoculum level, environmental factors (e.g. soil type, soil moisture regime and temperature) and disease control measures on the incidence and severity of diseases such as powdery scab (*Spongospora subterranea*), black scurf (*Rhizoctonia solani*) and black dot (*Colletotrichum coccodes*) under controlled environmental conditions and in field trials. As would be expected, these effects vary according to the pathogen; for example, the level of *S. subterranea* soil inoculum did not significantly affect the incidence and severity of either tuber infection or powdery scab symptoms at maturity, whereas a relationship between soil inoculum level and black dot disease symptoms

Disease	Pathogen	Reference
Silver scurf	*Helminthosporium solani*	Cullen, D.W. *et al.,* 2001. *European Journal of Plant Pathology* 107*, 387-398.*
Black dot	*Colletotrichum coccodes*	Cullen, D.W. *et al.,* 2002. *Plant Pathology*, 51, 281-292
Black scurf	*Rhizoctonia solani* AG3	Lees, A.K. *et al.,* 2002. *Plant Pathology* 51, 293-302.
Powdery scab	*Spongospora subterranea*	van de Graaf., P. *et al.,* 2003. *European Journal of Plant Pathology* 109, 589-597.
Dry rot	*Fusarium* spp.	Cullen, D.W. *et al.,* 2005. *Phytopathology* 95, 1462-1471.
Common scab	*Streptomyces* spp.	Cullen, D.W. & Lees, A.K. 2007*. Journal of Applied Microbiology* (in press).
Gangrene	*Phoma foveata*	Cullen, D.W. *et al.,* 2007. *Journal of Phytopathology* (in press).
Watery wound rot	*Pythium ultimum*	Cullen, D.W. *et al.,* 2007. *Journal of Phytopathology* (in press).
Pink rot	*Phytophthora erythroseptica*	Cullen, D.W. *et al.,* 2007. *Journal of Phytopathology* (in press).
Late Blight	*Phytophthora infestans*	Unpublished

Table 1 Real-time PCR assays developed at SCRI for the quantification of seed and soil-borne potato pathogens.

has been described. Additionally, it was demonstrated that root galling caused by *S. subterranea* increased significantly at 17°C compared to 12°C and this has implications for increasing soil contamination where root gall susceptible cultivars are grown (van de Graaf *et al.*, 2005).

Molecular diagnostic assays are an invaluable research tool, but are also being used on a larger scale in an industry driven BPC funded project led by SCRI. It is apparent that investigating seed stocks and soils for pathogens on a commercial scale and relating this to crop information is the most effective approach for validating diagnostic tests and interpreting their findings in relation to disease risk.

This work therefore combines diagnostic assays for several pathogens with appropriate soil sampling strategies and monitoring trials that encompass a wide range of cropping and environmental variables, in order to make the link between seed and soil contamination and the incidence and severity of disease outbreaks in commercially grown crops. Results are being collated in a database and interpreted in association with our knowledge of the epidemiology of the diseases. The assays and an interpretation of the results will be made available to the potato industry for disease risk assessment and decision making purposes, in conjunction with disease control advice.

References

van de Graaf, P., Lees, A.K., Wale, S.J. & Duncan, J.M. 2005. Effect of soil inoculum level and environmental factors on potato powdery scab caused by *Spongospora subterranea*. *Plant Pathology* **54**, 22–28.

scri
living technology

Quality, Health & Nutrition

Derek Stewart

In general the public, industries and policymakers perceive food as a basis for long term health, nutrition and quality of life and this aligns with the research aims of the programme. Through research we endeavour to establish the basis of health properties and organolepsis in major and minor crops with a view to optimising these and to determine what factors throughout the production chain impact upon these and other quality attributes. These aims are being achieved both under the auspices of the new SEERAD Science Programme as well as a raft of externally funded projects.

Health and Nutrition Ascorbic acid (Vitamin C) biosynthesis and regulation are still foci of research and *in planta* demonstrate a strong genetic component with regard to absolute levels whilst their agronomic manipulation have proved elusive. Elevation of ascorbic acid in blackcurrant through breeding is not a short process so current research is focussed on the development of predictive biochemical or genetic markers related to absolute ascorbic acid levels. This has involved sampling a seedling population which is being biochemically characterised using metabolomic technologies and the expression of four ascorbic acid biosynthetic genes assessed. This will allow us to assess genetic diversity within the ascorbic acid biosynthetic genes with a view to using them as predictive markers of fruit ascorbic acid concentration.

Fruit polyphenols are rapidly gaining credence as beneficial dietary bioactive compounds whose actions *in vivo* are suggested to impact positively on many human pathologies and conditions such as cardiovascular disease (CVD), cancer, inflammation etc. A concerted effort has been made to establish and validate efficacy for these compounds and we found that berry extracts exhibited significant anti-cancer effects in a human model cancer screen. Subfractionation of *Rubus* extracts resulted in significant inhibition of cancer cell growth with the constituent ellagitannins much more efficacious than the anthocyanins. Attempts to attribute a structure–activity relationship to the anti-cancer effects of these polyphenolics are ongoing. Supportive evidence for this was obtained in collaboration with the University of Ulster, wherein raspberry extracts were shown to be effective against the initiation, growth and invasiveness of colon cancer cells.

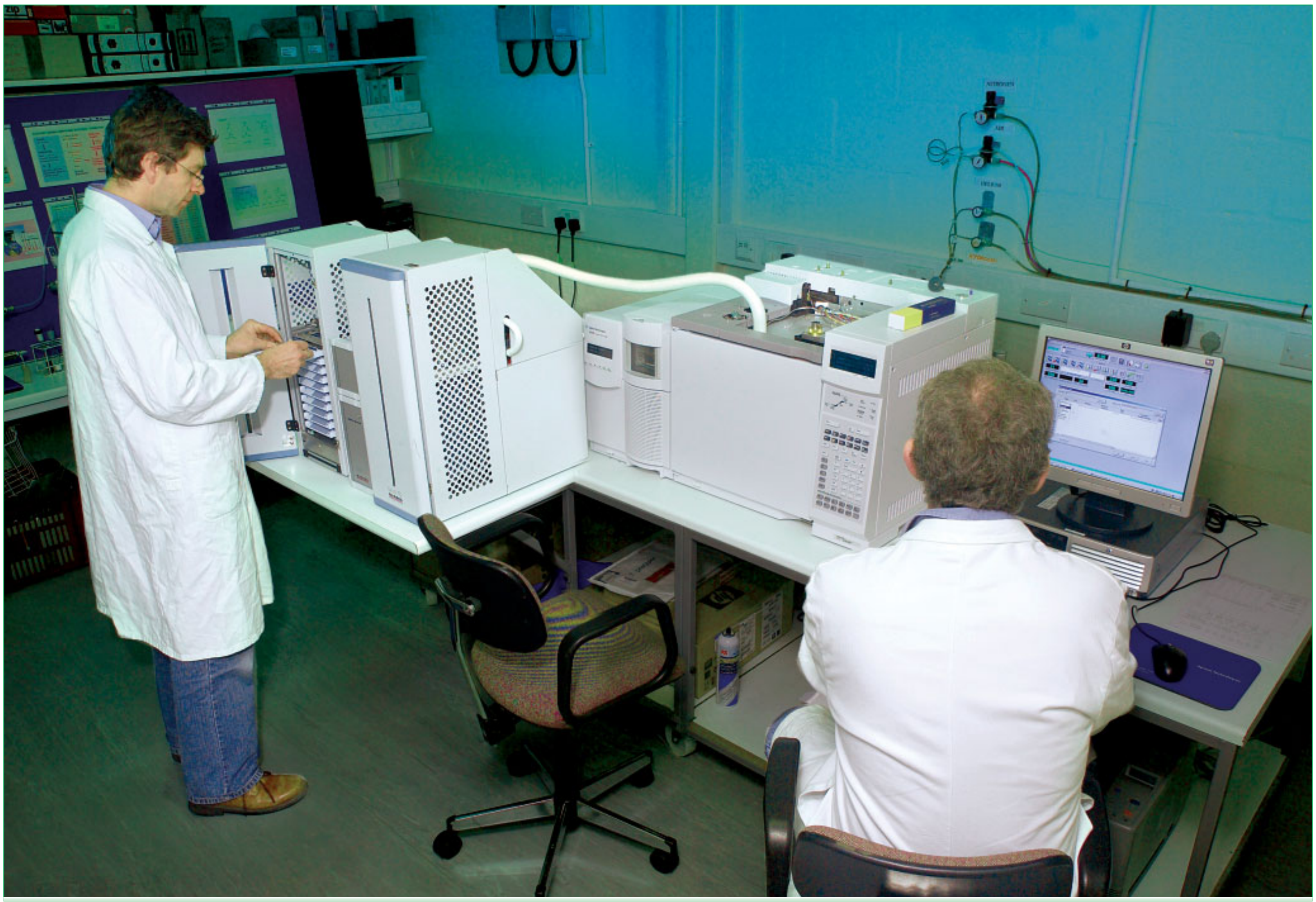
Interestingly the anthocyanins and ellagitannins were also shown to exhibit significant inhibitory activities against α-glucosidase and α-amylase, respectively. These enzymes are responsible for our ability to digest starch. Inhibition of α-glucosidase by drugs such as acarbose is a current therapy for controlling post-meal blood glucose levels in patients with non-insulin dependent diabetes mellitus (NIDDM). This raises the attractive idea of partial control of starch digestion and thereby blood glucose levels by dietary means, and this could at least in part ameliorate the impact or onset of NIDDM.

Research into the interdependency of food and health has been further strengthened by the appointment of two PhD students via the SCRI joint studentship scheme. These studentships will focus on the mechanism and preventative effects of soft fruit phytochemicals against cancer. These studies will further cement relationships with the Biomedical Research Centre (University of Dundee) and the Northern Ireland Centre for Food and Health (University of Ulster).

Aroma and Taste in Potato Aroma and taste are powerful drivers for repeated food purchases and potato is no exception. To establish the basis of these parameters in potato we have studied the components responsible for unique potato organoleptic parameters at the chemical, biochemical and molecular levels with a view to establishing markers in the raw tuber that can predict properties in the cooked/processed material. European (*Solanum tuberosum* Group Tuberosum) and Phureja potatoes (*S. tuberosum* Group Phureja, also known as *S. phureja*) have been shown to be distinct in sensory panels with respect to aroma and taste with Phureja adjudged to be the “better tasting”. Metabolite and volatile compound profiling of raw and cooked Tuberosum and Phureja lines followed by multivariate analysis suggested that there was a clear relationship between the elevated abundance of certain branched amino acids in tubers of raw Phureja relative to Tuberosum and similarly elevated levels of branched short-chain aldehydes in the volatile profile from cooked Phureja. In addition the levels of some fatty acids (*n*-hexadecanoic acid, 15-methylhexadecanoic acid and *n*-heneicosanoic) and some *br*-aldehydes (2-methylpropanal, 2-methylbutanal, 3-methyl-butanal) and methyl esters of short-chain branched acids (2-methyl propanoic acid methyl ester and 2-methylbutanoic acid methyl ester) were elevated in Phureja. Many of these compounds have been reported to have desirable organoleptic properties in other foodstuffs.

Studies into the differences in matrix chemistries between European and Phureja revealed that they differ with respect to umami taste. This is a heightened or elevated taste *per se*: a flavour enhancement category. We have compared the levels of one such class of compounds that give rise to the umami taste, in potato tubers that can be discriminated by taste trials. In tubers that score higher for acceptable flavour there are much higher levels of the umami compounds in cooked tubers. We believe this may be an important advance in our understanding of potato flavour and are extending this observation to a range of germplasm and segregating populations.

Food Quality and Safety Assessment Recent food safety incidents and the introduction of genetically modified foods in Europe have resulted in an intense public debate regarding the safety of the European food supply. Consumers have little confidence in the safety of their food supply and remain sceptical and distrustful of the management procedures currently in place. The overall objective of the EU project SAFEFOODS is to change the scope of decision-making on food safety from single risks to considering foods as sources of risks, benefits and costs that are associated with their production and consumption, and taking into account the social context in which decisions are made. With this framework in



mind the 3.5 million Euro work package co-ordinated by SCRI is using modern profiling techniques (transcriptomics, proteomics and metabolomics), to provide comparative analyses of crops produced by different breeding approaches (including GM), production practices (conventional, low input and organic) and in a range of geographic locations (e.g. UK, Germany, Poland, South Africa). Maize and potato are used as the model species. Data are emerging which illustrate the range and sources of variation in gene, protein and metabolite expression in crops which have a history of safe use. This data will be useful as a starting point in building global databases which will facilitate comparative safety assessment of GM crops, for example.

In a complementary study potato metabolite data derived from current and previous potato projects are being used as part of an FSA funded project to develop unified data models and data pre-processing strategies that should allow meaningful, standardised statistical analyses of metabolome variability to be undertaken in crop plants. This project, in collaboration with the University of Wales (Aberystwyth) and BioSS, will facilitate the unification of metabolite reporting globally and allow for the cross comparison of unique metabolomic datasets.

The advances made in both metabolomics, data handling and interpretation are being used to bridge the link between diet and health. One such study will use metabolomics to assess the impact of high anthocyanin-containing blackcurrant consumption on markers of CVD in early-stage CVD volunteers (in collaboration with University of Dundee School of Medicine). Similarly, within the EU project NOFORISK, metabolomics is being assessed as a platform technology to assess the safety of novel foods. Within NOFORISK metabolomics is being used to monitor an animal feeding trial for any unintended effects following consumption of a GM potato that has an altered and reduced glycoalkaloid content in comparison with the wild type potato. Both of these studies are ongoing.

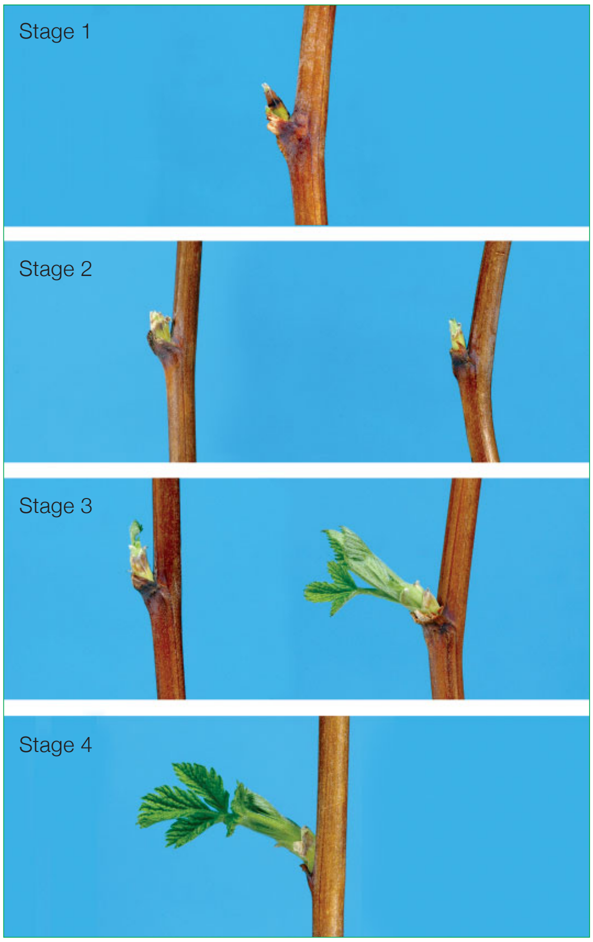
Understanding dormancy release in raspberry buds

Luca Mazzitelli, Robert D. Hancock, Sophie Haupt, Jim McNicol, Roberto Viola, Rex M. Brennan, Peter E. Hedley & Mark A. Taylor

The control of bud break through a temperature-dependent mechanism is a key ecological factor in woody perennial plant survival. Additionally, important aspects of plant architecture and development are regulated by the coordinated regulation of bud growth. Thus bud dormancy is fundamental to the study of plant developmental processes. Regulation of bud break is also of significant economic importance to fruit and horticultural industries. Bud break in protected raspberry crops is often poor and uneven, with many lateral buds failing to break at all. In order to extend cropping, current practice uses heated glasshouses, and therefore the ability to predict dormancy release becomes a major factor in early fruit production. Furthermore, such concerns are likely to become increasingly important for field production in a period of rising global temperatures.

Bud break of raspberry is dependent upon exposure to a particular duration of cool temperatures (chilling) to release dormancy followed by an appropriate temperature to permit growth in the spring. Usually, before and after the endodormant period (that is, when growth inhibition is regulated from within the bud itself) growth can be arrested at any time by unfavourable growth conditions. This physiological state is known as ecodormancy. Current theories of dormancy suggest that endodormancy is followed by a period of ecodormancy, where buds are held in a dormant state until temperatures rise in the spring allowing growth resumption. Raspberry also exhibits a high degree of paradormancy caused by apical dominance, which is manifested in the typical unbranched form of the canes. Although endodormancy and paradormancy both prevent visible signs of active growth of the cane, the two types of dormancy can be distinguished experimentally by growth comparison of buds on whole canes with buds on isolated nodal cuttings.

An understanding of the molecular and cellular basis of signals that control dormancy release in woody perennial plants remains elusive. Thus, this study aimed to unveil insights into the overall dormancy processes. Analysis of gene expression patterns, from the onset of dormancy in raspberry buds until the period when plants have accumulated sufficient chilling to permit bud break, provides the basis for a better understanding of the physiological processes within bud tissues. Important tools developed in this study include the generation and analysis of two dormancy stage-specific complementary DNA (cDNA) libraries constructed from endodormant and paradormant buds, expressed sequence tag (EST) analysis, and the development and



Four stages of raspberry bud development. Stage 1 – no development; stage 2 – bud swelling; stage 3 – growth of leaves extending away from the bud scales; stage 4 – second flush of leaves pushing through.

utilisation of a cDNA microarray. By combining these technologies, it was possible to monitor the activity of a large number of genes simultaneously and to identify differentially expressed genes encoding dormancy-associated proteins. Some of the selected genes with interesting expression patterns represent candidate markers for understanding the complex dormancy transition mechanisms. It is possible that key gene sequences identified could prove useful for future molecular breeding programmes, as molecular markers to aid the selection of desirable traits in commercial raspberry lines. The identification of dormancy stage-specific genes will also facilitate the isolation of promoter sequences conferring tight gene regulation during dormancy phase transition. Together with other ongoing raspberry investigations, including physical mapping and QTL analysis, the EST sequences and arrays developed in this project enable for the first time the large scale exploration of the raspberry transcriptome, making this plant a suitable model system for dormancy studies in woody perennials, especially other members of the Rosaceae. In particular, the array analysis has enabled gene expression profiling during a dormancy time course in a plant that has worldwide economic relevance for production of soft fruit and so we are able to draw conclusions about the metabolic activities taking place during dormancy release in bud meristems, providing the basis for the development and testing of hypotheses concerning dormancy release processes.

Reference

Mazzitelli, L., Hancock R.D., Haupt, S., Walker, P.G., Pont, S.D.A., McNicol, J., Cardle, L., Morris, J., Viola, R., Brennan, R.M., Hedley, P.E. & Taylor, M.A. 2007. Coordinated gene expression during phases of dormancy release in raspberry (*Rubus idaeus* L.) buds. *Journal of Experimental Botany* (in press).

Acknowledgement

This work was funded by the Department for Environment, Food and Rural Affairs, project code HH203 NSF.

Metabolomic analysis of the potato tuber life cycle

Louise V.T. Shepherd, Derek Stewart, Nathalie Massat, Michael Anderson, Paul Neave, Jim McNicol & Howard V. Davies

The potato tuber is a valuable model system for studying sink organ formation and storage organ metabolism. With the emergence of modern platform "omics" technologies (transcriptomics, proteomics and metabolomics) approaches are being developed to facilitate a much deeper understanding of the tuber life cycle, from tuber initiation through development and storage and into the sprouting phase. "Omics" approaches, linked to appropriate phenotyping, will allow a clearer definition of temporal changes in trait development and the identification of genes, proteins and metabolites driving these events. They will also facilitate a fuller understanding of the drivers of genotypic variation in commercially important phenotypes.

We have used a range of metabolite profiling approaches to understand better the complexity of events at the metabolite level during the potato tuber life cycle. Through collaboration with BioSS the complex data sets have been analysed using multivariate techniques such as principal component analysis (PCA) and, where applicable, for individual compounds analysis of variance (ANOVA).

Glasshouse grown plants of *Solanum tuberosum* cv. Desirée were harvested sequentially over about 5 months to obtain tubers at predefined developmental stages. Tuber sub-samples were freeze-dried and milled prior to analysis by gas chromatography–mass spectrometry (GC–MS).

Analysis of polar constituents using GC-MS was able to discriminate between most of the life cycle stages examined and in particular between the developing and mature tubers (Fig. 1). There were smaller differences between mature and sprouting tubers using these co-ordinates. However, separation of mature and sprouting tubers was possible using other principal components which accounted for a lower percentage of the variance. Cold stored tubers (5 °C) were easily separated from those stored at room temperature and this was primarily driven by differences in sugar content. The fact that stage 5a (excised developing tubers) could be separated from 5b (tubers maintained attached to the mother plant) was particularly interesting as was the fact that excised tubers clustered more closely to the naturally senesced tubers. This indicates that the excision of developing tubers from the mother plant stimulates the tuber maturation process and is in line with our previous studies which showed that excised tubers undergo a rapid sink to source transition with a reduced capacity to synthesise starch. As with transcriptional changes during the life cycle (Kloosterman *et al.*, 2005) metabolites could be grouped depending on the pattern

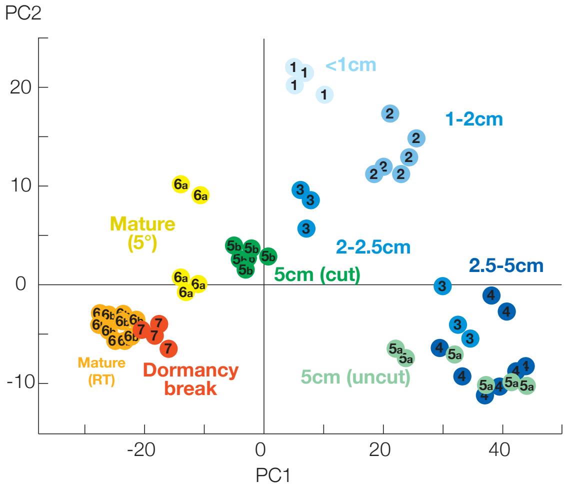


Figure 1 Principal component analysis of 90 polar metabolites identified by GC-MS for tuber life cycle stages 1-7. Samples are labelled according to developmental stage.

Life cycle stages for metabolomics

- 1 Small developing tubers (<1 cm diameter);
- 2 Small developing tubers (1-2 cm diameter);
- 3 Small developing tubers (2-2.5 cm diameter);
- 4 Small developing tubers (2.5–5 cm diameter);
- 5a Larger developing tubers (5-6 cm diameter; excised from plant and stored at 10°C for 3 days);
- 5b Larger developing tubers (5-6 cm diameter; not excised but sampled at the same time as 4a);
- 6a Mature tubers stored at 5°C for 4 weeks;
- 6b Mature tubers stored at room temperature for 4 weeks;
- 7 Mature tubers (dormancy broken at 5°C followed by 2 weeks at 10°C; sprouts ca 1 cm long).

of change observed and the specific stages in tuber development/maturation when significant changes became manifest. While it is clear is that metabolites change with development the fact that mature dormant and non-dormant tubers appear to be relatively uniform in their metabolite profile within a cultivar gives some confidence for experiments which use mature tubers to assess, for example, the extent of natural variation or the impact of specific transgenes on composition, i.e. there appears to be a window of relative stability in the metabolome.

Reference

Kloosterman, B., Vorst, O., Hall, R.D., Visser, R.G.F. & Bachem, C.W. 2005. Tuber on a chip: differential gene expression during potato tuber development. *Plant Biotechnology Journal* **3,** 505-519.

scri
living technology

Environment Plant Interactions

Philip J. White

Research in the EPI programme seeks to describe, understand and predict how the environment impacts on plants, and how plants modify their environment – an environment that changes physically, chemically and biologically in both space and time. We focus on the efficient use of resources, such as water and minerals, and the development of sustainable and resilient arable ecosystems. We are committed to communicating our research to academics, industry, policy makers and the public in general.

Roots provide anchorage for a plant and stabilise soils In an EPSRC-funded collaboration with engineers at the University of Dundee, Glyn Bengough and Paul Hallett have demonstrated recently the beneficial effects of living roots in mechanically reinforcing soils, particularly on unstable slopes. Insights from this work have informed the landscape management strategies of organisations such as Network Rail. Our research has also identified key mechanisms involved in the development of soil structure by roots and microorganisms. Scientists from SCRI visited China and Nepal under the EU AsiaLink programme to lecture on the complex interactions between the biological and physical properties of the soil and their consequences for sustainability.

Roots explore the soil to acquire water and essential minerals In collaboration with the QHN programme, we have been analysing the composition of root exudates and its consequences for the movement of roots through the soil, releasing minerals from recalcitrant substrates, and fostering synergistic interactions with biota in the rhizosphere. Because crop growth can be constrained by physical properties of the soil, Blair McKenzie and Tracy Valentine are identifying traits that enable roots to penetrate compacted soils. In a BBSRC-funded collaboration with computer scientists at the University of Dundee, Glyn Bengough and Tracy Valentine have been developing novel computer-vision techniques to automate the analysis of root growth over short time intervals using confocal microscopy and particle image velocimetry.

Improved fertiliser use efficiency reduces costs and pollution The EU Water Framework Directive seeks to reduce the nitrogen (N) and phosphorus (P) concentrations in surface and ground waters and, thereby, restore them to good ecological quality. To appraise the current situation, Defra commissioned Philip White and John Hammond of Warwick–HRI to update the estimates of the sources of P in UK waters. Their report indicated that agriculture contributed substantially to P pollution, and that improving P-fertiliser use efficiency would benefit the environment. This advisory work was complemented by SEERAD-funded research to identify genetic and agronomic factors to improve the use of P and N fertilisers. In parallel work, Tim George demonstrated the significance of genetic variation in rhizosphere phosphatase activity for plant P nutrition in soils with low phosphate availability.

Interactions in the rhizosphere improve plant growth and soil resilience Using a combination of traditional and molecular techniques, scientists at SCRI are able to survey complex microbial communities. In a commercial context, Scottish Enterprise is funding Tim Daniell to develop high-throughput diagnostic techniques to identify micro-organisms impacting on environmental and water quality. In an academic context, and with a focus on below ground communities, Tim Daniell has been studying the population dynamics of nitrogen cycling organisms with Ron Wheatley and the relationships between plants and their intimate symbiotic partners, such as arbuscular mycorrhizal fungi, with Maarja Öpik. In collaboration with scientists at Nanjing Agricultural University, Bryan Griffiths has shown that bacterial-feeding nematodes alter root development through changes in the rhizosphere microbial community that affect the production of plant growth regulator substances. Our studies of the resilience of soils in response to changes in agricultural practice have indicated that, whilst the physical properties of soils can improve quickly, the recovery of biological functions can take many years.

Interactions between plants and insects An area of ecological research that is rarely undertaken in managed ecosystems is the linkage between below ground and above ground biota. However, Scott Johnson, Nick Birch and colleagues have shown that even minor root herbivory by vine weevils can compromise the resistance of raspberry plants to the large raspberry aphid. Since this aphid is a vector of several major viral diseases of raspberry, this may have serious consequences for the industry. Research is now underway to determine the processes behind this phenomenon, with a view to improving plant resistance to pests. In other entomological research, Ali Karley is investigating both the effect of plant macronutrient status on plant–insect interactions and the role of aphid microbial symbionts in aphid–plant and aphid–parasitoid interactions.

Studies of the non-specific consequences and spread of transgenes in the environment This year, Bryan Griffiths and colleagues reported results from the EU ECOGEN (soil ecological and environmental evaluation of genetically modified crops) project. This project undertook field and glasshouse trials across Europe that included herbicide tolerant and Bt-maize. The data indicated that soil biology was affected greatly by soil type, tillage treatment and the stage of plant development. Factors such as crop cultivar and application of biocide had lesser effects on soil biology, and smaller still were effects attributable to genetic modification (GM). The EU SIGMEA (sustainable introduction of GM crops into European agriculture) project and several complementary Defra-funded projects led by Geoff Squire were also successfully completed, or produced major outputs, this year. The analysis of over 200,000 plant samples has provided unique insights to GM persistence in near-commercial arable ecosystems, and this knowledge has been used by Graham Begg and colleagues to develop mathematical models of gene flow in the environment. These comprehensive studies have not only informed policy makers, farmers and commercial parties, but are also enabling the development of novel techniques to study the movement and persistence of genes that underpin ecologically important traits. In related SEERAD-funded work, Pete Iannetta and colleagues are developing diagnostic molecular tests for key functional traits in plant populations as a measure of ecosystem diversity, using ecotypes of *Capsella* (shepherd’s purse) as a model system.

Gladys Wright and Ron Wheatley beside an automatic weather station monitoring the environment near Mid Pilmore field plots with contrasting cultivations.

The role of plant diversity in sustaining food webs in arable ecosystems The extensive farm scale evaluations of arable biodiversity in GM crops conducted between 2000 and 2003, and subsequent SCRI investigations of seedbank diversity and GM persistence, have provided data for us to identify functional types of weed and invertebrate species and to model the relationships between weed density and crop yield. This year, Cathy Hawes and colleagues began a BBSRC-funded research project to model, and ultimately provide advice on, strategies for maintaining biodiversity within arable systems whilst maintaining crop yield, in collaboration with Dave Bohan of Rothamsted Research. This project is synergistic with other SEERAD-funded studies to elucidate the complex relationships between crop yield, biodiversity, sustainability and ecosystem resilience. In one of these, Bruce Marshall and Ali Karley are developing techniques to quantify and explore the influence of plant architecture, through its impact on competition for light and nutrients, on food webs and species diversity in arable ecosystems.

The Environment Plant Interactions Programme supports 'The Living Field' An educational project informs schoolchildren, in particular, and the public, in general, about the importance of the environment, agriculture and science. Several members of the EPI programme have manned popular exhibits at Gardening Scotland and the Dundee Flower and Food Festival to promote the opening of the Living Field Study Centre at SCRI in Spring 2007.

Dynamics of root–soil systems

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

Plant roots experience a range of stresses in the soil environment, and also have capacity to modify the physical behaviour of soil. As agricultural practice becomes increasingly mechanised and more concern is placed on the ecosystem services provided by soils, understanding these complex root–soil interactions is essential to developing sustainable cropping systems. In combination with climatic factors, such as the frequency and intensity of rain, soil mechanical and hydraulic properties control the size, nature and extent of root systems. These constraints can affect crop yield and quality. Given the uncertainties associated with global climate change, it is crucial that we both understand and manage the soil–plant system to deliver stable crop yields whilst enhancing biodiversity in agroecosystems, and minimising environmental pollution by agrochemical leaching. We are therefore studying root responses to soil physical conditions, from the molecular level to field scale, to understand how roots respond to changes in soil strength, structure and water potential.

The extent of a root system controls the volume of soil the plant can exploit for water and nutrients. Root length densities (length of root per volume of soil) are often large in fertile agricultural topsoils. However, in subsoils and poorly structured topsoils, roots can be confined largely to pre-existing channels and biopores, decreasing the efficiency of water and nutrient extraction. The main physical factors limiting root growth are mechanical impedance (soil that is too hard), drought (insufficient available water), and waterlogging (insufficient air-filled pore-space). By quantifying how these stresses change with time and location in the soil profile, we can understand the stresses limiting root growth. Results to date indicate that soil strength is often the major factor limiting root growth. We are evaluating how soil strength may be controlled by soil management and its subsequent effects on plants.

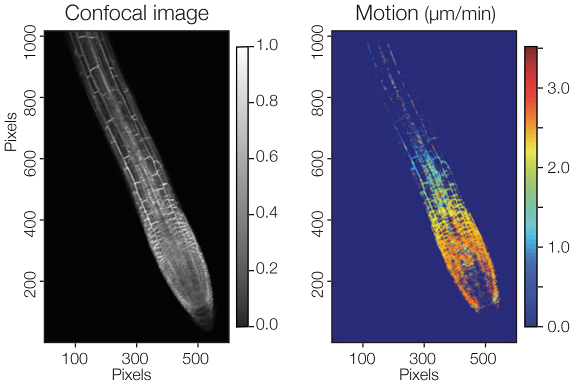


Figure 1 We are developing image analysis techniques to study physiological mechanisms underlying root responses to stress. This figure shows the cellular motion caused by cell expansion in growing *Arabidopsis* roots (BBSRC funded).

We are particularly interested in whether certain plant genotypes perform better in problem soils, because we have evidence of significant genotypic variation in root systems of both model plant and crop species. As rainfall frequencies and intensities change, plant roots may be faced with an increasingly hostile soil environment. Working in collaboration with BioSS and the Macaulay Institute we aim to understand how we can best evalu-

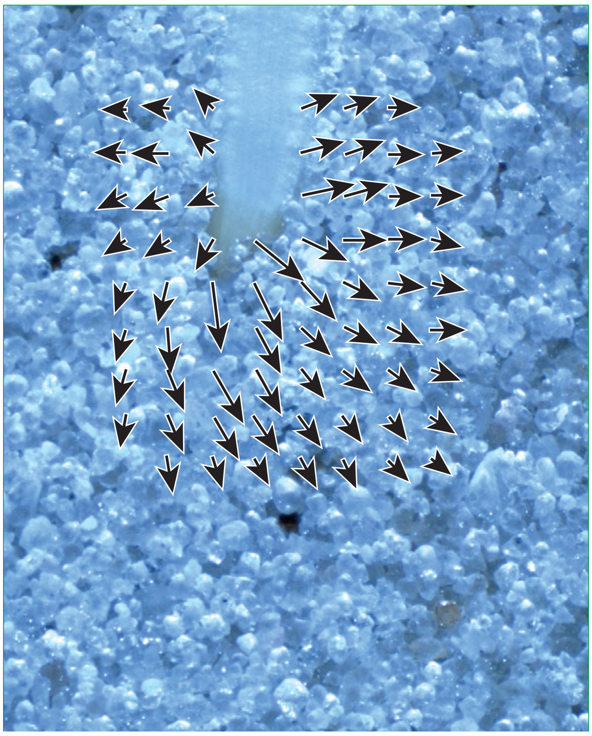


Figure 2 Deformation patterns around root tips growing in sand reveal the mechanics of root penetration.

Quantifying root systems grown in soil columns reveals interactions between root architecture and root function.

ate soil physical properties at a national scale, control them at a field scale and, alongside plant geneticists at SCRI, understand the potential to exploit variation in root system traits for efficient capture of water and nutrients.

The most detailed work involves developing techniques to study the dynamics of cell expansion in relation to external stresses. For example, Fig. 1 shows results from a new image analysis method developed in collaboration with the department of Applied Computing at the University of Dundee (Tim Roberts and Stephen McKenna) to determine the rates of cell expansion in roots of the model plant species *Arabidopsis*. We have recently applied a related technique to study deformations of the soil around growing roots (Fig. 2), in collaboration with the Agricultural University of Norway (Ane Vollsness). Developing these methods and applying them in novel ways elucidates the mechanisms controlling root penetration of soils, whilst scaling up to the glasshouse and the field allows consideration of whole root system responses under real conditions.

Common wild plants as biodiversity indicators

Pietro Iannetta, Graham Begg, Jane Wishart, Mark Young, Ali Karley, Tracy A. Valentine, Cathy Hawes & Geoff Squire

Wild plants commonly termed ‘weeds’ are species stereotyped as being survival specialists. However, this presumption anticipates *ex gratia* the ability of a wild plant species to adapt to a changing environment. This assumption contrasts with our awareness of crop species, which are characterised by a range of different cultivars or varieties, each distinguished by their ability to exhibit one or more profitable traits, such as high yield, strong stems, short time to flowering or reduced seed dormancy. A farmer normally selects a particular variety based upon local conditions. Wild plants should not be considered as different from crops in this respect, since a single wild plant species also comprises a myriad of functionally different forms. Consequently, the ability of wild species to adapt should perhaps not be assumed as a species-property, but rather as a property of the collection of functionally distinct types that comprise that species.

The breadth of variation within a species is an important element of the biodiversity of wild plant species and may relate directly to other components of the ecosystem such as management history, soil quality, and the biodiversity of associated trophic layers, including microorganisms, insects and birds. We are currently testing whether there is a causal link between the within-species diversity of wild plants and other components of the ecosystem. If such a link were found, it might provide a means for rapid assessment of the state of a habitat.

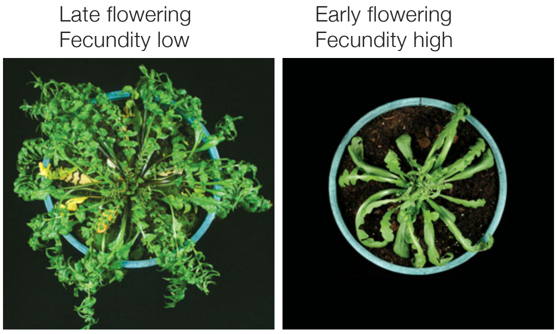


Figure 1 Two extremely different phenotypes are exemplified in the picture. Relatively early flowering plants encompassed *ca*. 85% of the accessions. Flowering quickly was also associated with a longer reproductive duration and the production of more (and smaller) seeds, compared to late-flowering accessions.

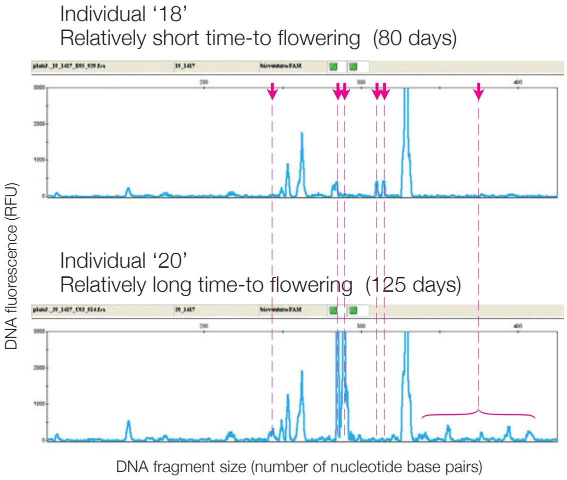


Figure 2 Molecular-fingerprinting techniques are being developed as diagnostic tools. Among these, molecular I-SSR (Inter-Simple Sequence Repeat) data provided the profiles shown above for two *Capsella* accessions with relatively long (125 days) and short (80 days) flowering times. The down-arrows and associated dash-lines highlight the presence and absence of DNA regions that distinguish the functionally different types.

Our research presents a novel approach, quantifying biodiversity and assessing the ecological impact of environment changes. The most scientifically accurate quantifications demand that a suitable measurement unit is defined. Historically, the measurement units for biodiversity have been species. However, species are defined largely by the structural characteristics of (for example) their stems, leaves and flowers which do not necessarily serve as indicators of their ecological function. We aim to recognise plants as individuals defined by what they actually do in terms of their ecological service and define the units to measure biodiversity in terms of ecologically significant traits.

To test the utility of our model approach, we have first assessed diversity (Fig. 1) within the common wild plant

A critical mass of highly skilled scientists is an essential component for the most efficient research projects, particularly for ecological studies. The environmental monitoring of natural plant communities demands professionally managed teams to process large numbers of samples, often within short time frames. Team co-ordination also exists across research establishments: here members of the EPI team sort leaf material gathered from across the UK.

Capsella bursa-pastoris (L.) Medic. (meaning, "*little purse-of the shepherd*" in reference to pouches traditionally worn in the Mediterranean area). It was from centres of diversity in this region that *Capsella* radiated to be grown as a food-crop and medicine throughout Europe and beyond, which may explain its prevalence as a colonist of disturbed land worldwide. The wide range of within-species variants has long been acknowledged and recorded since the mid-1800s, with up to 200 types being noted.

Our research has shown that over 85% of all the *Capsella* individuals gathered from farmed fields throughout the UK are relatively quick to flower compared to other arable plants. In addition, wide variation was also found for other ecologically important life history traits for *Capsella*. These include seed and root characteristics and leaf shape, size and number. The implications of trait-imbalance upon other components of the ecosystem, such as resource quality for insect herbivores and crop pathogens, are also being explored.

Molecular diagnostic tests for the trait differences are being developed to estimate the balance of traits for *Capsella* populations that exist on land subject to differing conditions of management and climate (Fig. 2). This information will provide a valuable insight to our understanding of the role that wild plants play in production ecosystems and provide essential information for government policy-makers.

scri

living technology

Plant Research Unit

of the University of Dundee

Claire Halpin

The Plant Research Unit of the University of Dundee continues to thrive at SCRI. It is now part of the newly formed College of Life Sciences following the restructuring of the University from seven Faculties to four Colleges. This change in academic structure and management will enable the University to continue to build on its recent successes in a rapidly changing and competitive environment. The College is a world ranking research centre and the only 5 biological sciences grouping in Scotland. The College employs over 650 scientists and support staff, including 68 principal investigators, from 49 countries working in state of the art facilities on the city campus. The University's Plant Research Unit located at SCRI currently has 25 people (plus visiting scientists) working in five research groups. Collectively, the Unit published over 30 papers in 2006 and won nine new research grants. The Unit is increasingly working in close collaboration with SCRI researchers and joint grant applications totaling over £3.2 million were submitted in 2006. The main activities of the Unit's five research groups during 2006 are summarised below.*

Genome evolution and biodiversity in crop plants (Dr Andy Flavell) Crop genomes have been selected from wild progenitors by thousands of years of human selection, leading to a big reduction in biodiversity. The Flavell group has developed high throughput molecular marker methods to measure this diversity, using polymorphism both at single nucleotides (SNPs) and in transposable element insertion positions. These marker approaches are being applied to the improvement of fungal resistance in wheat and potato, in partnership with SCRI (Robbie Waugh, Glenn Bryan) in the EU Framework 6 Project BIOEXPLOIT (joint value to SCRI/UoD £1.25 million). Andy Flavell is also closely collaborating with David Marshall and colleagues at SCRI to refine the GERMINATE database for storing, manipulating and displaying data related to plant biodiversity. This work is supported by the BIOEXPLOIT project and a new BBSRC Project grant, GERMINATE 2, which commences early in 2007. The Flavell group is also analysing biodiversity of pea (*Pisum sativum*) in the EC Framework Project GRAIN LEGUMES. Finally, Andy Flavell and Robbie Waugh have co-supervised the PhD project of Maura Lyons to identify Miniature Inverted Repeat transposable elements (MITEs) in the barley genome. Maura submitted her PhD in September 2006.

Manipulation of plant metabolism by reverse genetics (Dr Claire Halpin) Current approaches to metabolic engineering in plants have several drawbacks. Most work to date has concentrated on modulating the expression of single genes and available procedures for coordinately manipulating multiple genes are arduous and time-consuming. Transgenic technologies are still imprecise and it is currently impossible to directly target a transgene to a specific genomic location or to perform 'gene-knockouts' in higher plants. Claire Halpin's group is interested in developing strategies for achieving coordinate multi-gene manipulation and gene targeting in plants, focussing particularly on manipulation of the lignin biosynthetic pathway. A recent grant from The Leverhulme Trust is funding continuing research into homologous recombination and gene targeting in the Halpin lab. Also in 2006, Claire Halpin, in collaboration with SCRI researchers (Robbie Waugh, David Leader and Derek Stewart) submitted several proposals to BBSRC to allow her to expand her lignin research into barley.

Plant ecophysiology and adaptation to environmental stress (Professor Lyn Jones) Environmental stresses such as drought and salinity limit agricultural production over a large proportion of the world's land area. Research in Prof. Lyn Jones's group aims to understand the ways in which plants can tolerate individual environmental stresses such as drought and salinity as a basis for improving both the genotypes available for agriculture and for improving crop management for stressful conditions. A particular thrust of the research in the past few years has been the development and refinement of remote sensing techniques for diagnosing and monitoring plant responses to various environmental stresses. Techniques being developed range from those applicable at the single leaf or plant scale through to regional sensing by means of airborne or satellite-based remote sensing. The work has a particular focus on novel approaches to the use of thermal imaging as a tool for assessing the rate of water loss from plant canopies and as a sensitive tool for drought 'phenotyping'. Lyn Jones outlines the potential of thermal imaging as a tool for the diagnosis and monitoring of plant responses to environmental stresses, especially drought, in the following article.

Resource availability ('Bottom up') effects on the functioning of photosynthetic organisms (Professor John Raven FRS FRSE) John Raven's main research activities during 2006 have been in three distinct areas. (1) *Inorganic Carbon:* Work published in 2006 on the tropical and warm temperate marine green acellular macroalgal genus *Caulerpa* showed great diversity of inorganic carbon acquisition processes among the eight species studied. As yet unpublished work shows diversity with the marine diatom genus *Thalassiosira.* (2) *Photosynthetically Active Radiation (PAR):* Papers published this year have increased our understanding of the factors limiting the use of very low fluxes of PAR in photolithotrophic growth of two species of marine algae, and have extended John Raven's earlier work on limitations on where life based on photosynthesis could occur elsewhere in the universe rather than on Earth. (3) *Trace Elements:* Work published in 2006 examined a wide phylogenetic range of marine microalgae for the effects of the PAR for growth on the content of a number of trace elements; for some elements in some organisms very high quotas were found at the lowest PAR values tested. While these findings require further mechanistic examination to determine if the large quotas have functional (catalytic) significance rather than representing luxury accumulation, they clearly have important implications for the allocation of trace elements between seawater and cells at differ-

ent depths in the surface ocean. All of this work involved collaboration nationally and internationally.

Identifying the genes that control flowering time and understanding how they are regulated (Dr Gordon Simpson) One gene that strongly promotes flowering in different plants is Flowering Locus T (FT). *Arabidopsis* mutants that ectopically express FT flower early. Gordon Simpson's lab has successfully screened for mutants that flower early in the absence of FT. The aim of this study is to identify factors that work alongside or downstream of FT in the control of flowering. The isolated mutants show different responses to day-length and ambient temperature. Progress towards characterising these mutants is being made and in 2006 Stephen Holland, a student at Dundee University, won a fellowship from the Genetics Society to begin positional cloning of the genes disrupted in these mutants. Gordon Simpson's lab is already focussing on molecular and genetic studies to determine how an Arabidopsis RNA binding protein called FPA promotes flowering. With funding from the BBSRC, Dr Lionel Terzi and Dr Jacqui Marshall have joined the lab to study the RNA targets of FPA. They are applying new technology (RIP and CLIP) to Arabidopsis that involves the isolation of complexes of RNA binding proteins with their cognate RNAs formed *in vivo*. If successful, this technology will be valuable beyond the field of flowering as it would provide a means to directly identify the genes regulated by the many plant-specific RNA binding proteins of unknown function. Gordon Simpson was one of 10 young plant developmental biologists invited to a UK–China partnering meeting in 2006 from which collaborations in regulatory RNAs are being developed.

Thermal imaging as a tool for studying plant responses to environmental stress

Hamlyn G. Jones, Stefania Pisanu, Pietà G. Schofield & Ilkka Leinonen

Leaf temperature is important to plants both through its subtle effects on the rates of key physiological processes and because of the damaging effects of extreme temperatures. Because of the importance of evaporative cooling as a major component of the leaf energy balance, leaf temperature can be used as an indicator of rates of water loss or of stomatal opening. Although in principle one could also use temperature measurements to study changes in thermogenic metabolism, these differences are usually too small to detect in the field, so most applications of thermal imaging in plant ecophysiology relate to changes of transpiration in response to environmental stress. Modern thermal imagers can readily detect small differences in transpiration reflecting differences in stomatal aperture (Fig. 1); as a result thermal imaging can be a powerful tool aiding the diagnosis and monitoring of plant responses to environmental stresses.

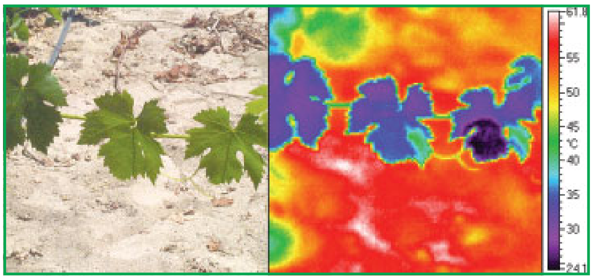


Figure 1 A visible image and a corresponding thermal image of grape vine leaves, indicating the cooling effect of evaporation. The cool area of the right hand leaf (dark purple, *c.* 25°C) has been wetted while warm areas (blue-green, *c.* 40°C) are where transpiration has been prevented.

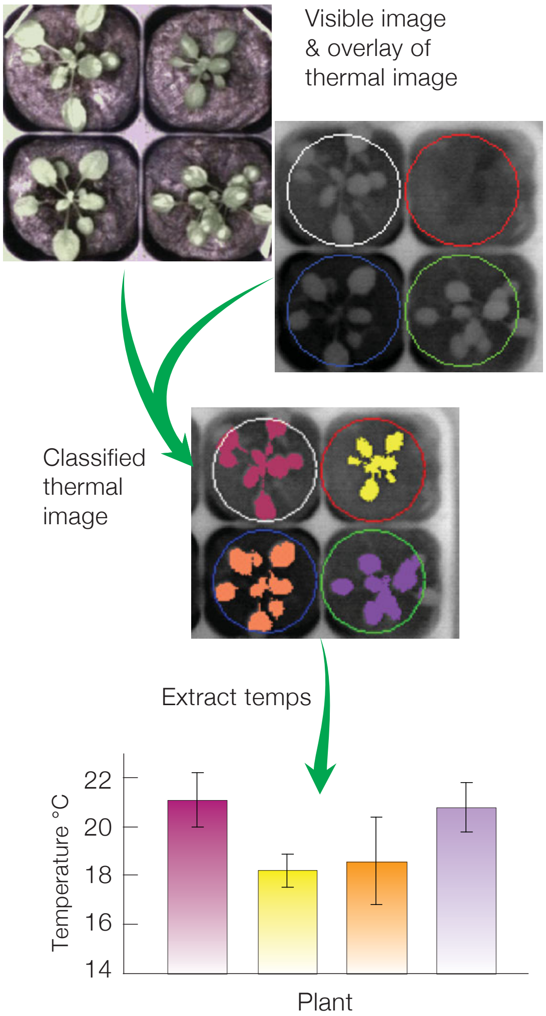


Figure 2 The automated procedure for extraction of leaf temperatures involves the combination and overlaying of thermal and visible images, image classification to identify leaf areas and extraction of temperatures.

Irrigation scheduling Monitoring of canopy temperatures has been used for some years to indicate the need for irrigation, but it has not been very sensitive in temperate climates. We have introduced thermography, which together with the use of wet and dry 'reference' surfaces, has opened up exciting new possibilities for irrigation scheduling in a much wider range of situations. When combined with modern image analysis techniques it is possible to automate the extraction of leaf temperature and potentially even to automate an irrigation control system. We are currently collaborating in a Defra LINK project aiming to devise an automated irrigation controller for the hardy nursery stock industry. The principle of the extraction of leaf temperatures from combined thermal and visible images is illustrated in Fig. 2.

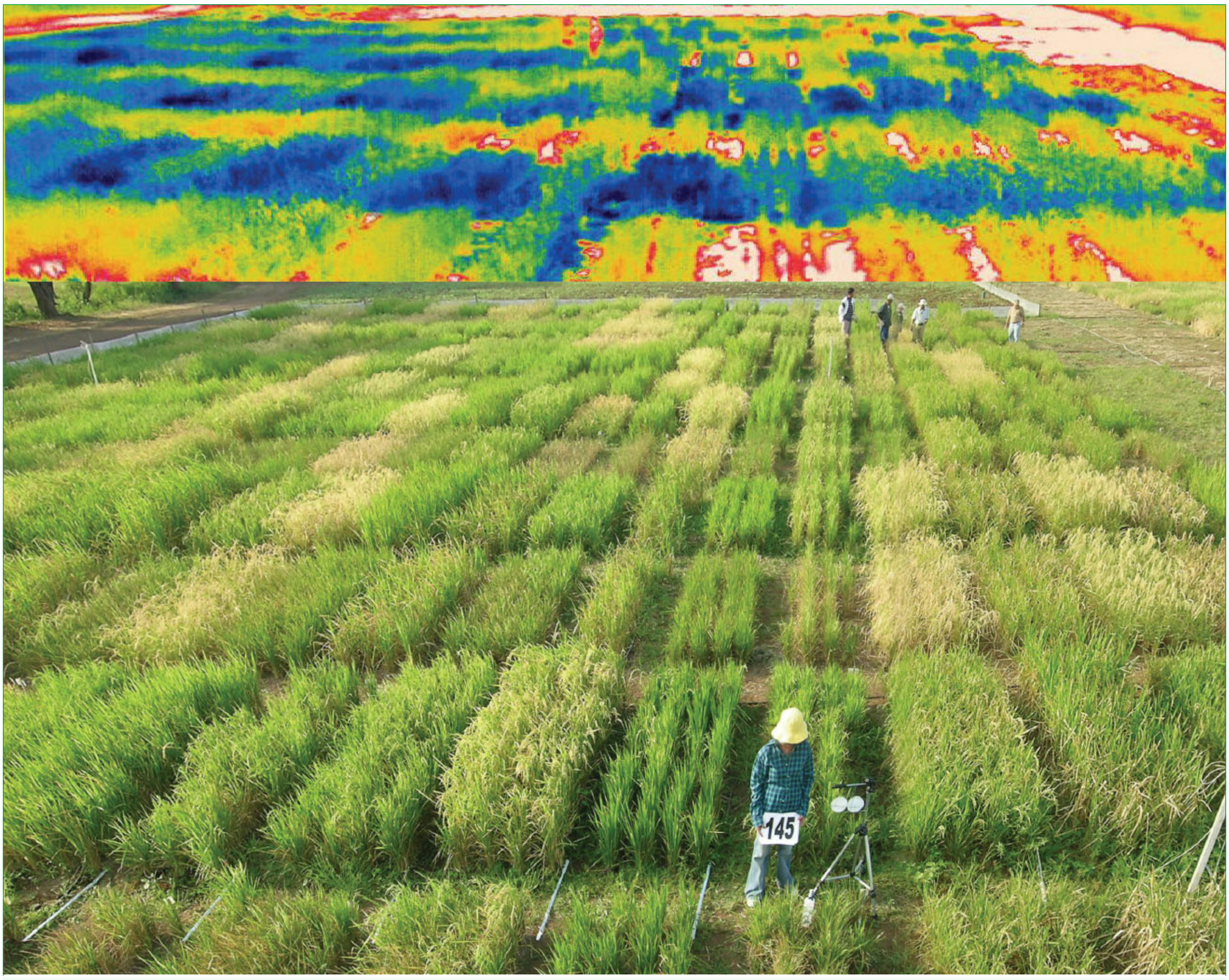


Figure 3 Field “macro-array” of rice genotypes being tested for drought response together with a corresponding thermal image showing genotypic variation in canopy temperature. (Collaboration with International Rice Research Institute).

Drought “phenotyping” Another powerful application of thermal imaging is to provide a rapid means for screening for stomatal mutants or for the identification of genotypes with particular stomatal responses to imposed drought. Thus far thermography has successfully been used to identify a number of stomatal mutants; our work has concentrated on its application in field studies where it is important to have tools available that allow large-scale phenotyping of breeding material in field arrays (Fig. 3).

Use in evaluation of canopy structure. Thermal imagery can also be combined with multiangular viewing and hyperspectral reflectance for the diagnosis and monitoring of water and nitrogen stresses in various agricultural crops. The multi-angular visible images can be analysed to extract the leaf area index and leaf angle distributions (the latter indicative of wilting in response to water deficits). The thermal data provide information on stomatal responses while the spectral reflectance data indicate pigment changes such as chlorophyll concentration that can be indicative of nutrient stresses such as nitrogen deficiency.

living technology

Biomathematics and Statistics Scotland

David A. Elston

Biomathematics & Statistics Scotland (BioSS) provides specialist quantitative support for all four of SEERAD's research programmes. This breadth of purpose distinguishes BioSS from the other elements of the SCRI Group, and is achieved through a dispersed group of statisticians, modellers and computing experts based at BioSS centres in Edinburgh, Dundee, Aberdeen and Ayr. Hence the science in SEERAD's main research providers benefits from proximity with BioSS staff, whilst BioSS staff benefit from being part of a substantial grouping of fellow professionals.

A central theme in 21st century scientific development is increasing quantification, driven by increases in computer processing power, in the rate of collection of data and in the size and connectivity of databases. By employing statisticians, modellers and computing experts at centres of scientific research throughout Scotland, BioSS is perfectly positioned to recognise and address the new quantitative challenges posed by emerging technologies. Almost all scientific staff undertake methodological development (BioSS research work) while working closely with non-mathematical scientists to address scientific problems using existing methodologies (BioSS consultancy work). This approach maximises effectiveness by ensuring both research focus and up-to-date consultancy practice.

BioSS manages its consultancy work under the four broad scientific areas:

- plant science;
- animal health and welfare;
- ecology and environmental science;
- human health and nutrition.

In each area, BioSS staff have a wide range of different types of interaction with scientists, ranging from the provision of short pieces of advice that allow BioSS expertise to guide a large number of scientific research projects, through to deep collaborative relationships that allow BioSS staff to make substantial inputs to a small number of scientific projects in which quantitative issues play a central role. Whilst the following highlights describe collaborative interactions, the cumulative importance of the advisory inputs should not be underestimated.

Our consultancy work for plant science supports scientists investigating the genetics of important Scottish crops such as potatoes, barley and soft fruit, the diseases that inhibit production of these crops and the interactions between arable crops and the environment. Improved plant varieties can be selected more quickly using molecular markers shown to be linked to genes for key traits, such as gall mite resistance in blackcurrant. Linkage maps have been developed in collaboration with SCRI for blackcurrant and raspberry, both outbreeding species in which breeding populations may be complicated by occasional self-fertilisation of parental plants. BioSS has developed methods for mapping QTLs for traits such as root rot that are recorded as repeated categorical measurements.

Our consultancy work for animal health and welfare supports scientists investigating the bacterial, viral and parasitic diseases of farm animals, husbandry-related welfare issues and the interaction of agricultural practices in animal farming systems. BioSS has recently collaborated with the Moredun Research Institute in the design and analysis of a survey of sheep farmers, investigating the disease and welfare problems which they believe have the most impact on flocks. The identification of diseases such as sheep scab and problems such as anthelmintic resistance, being of particular relevance to Scottish farmers, will allow better targeting of scientific effort within the animal health and welfare programme.

Our consultancy work for ecology and environmental science supports scientists investigating soil health, water quality, and ecological communities, with the aim of understanding and managing the interactions between the rural economy and the environment. The impacts large herbivores have on extensive tracts of upland vegetation have been assessed in collaboration with the Macaulay Institute. The BioSS contributions to this collaboration have included development of appropriate sampling and data collection protocols and the development under our research programme of methods to analyse spatially distributed, ordinal data. Of particular interest is the relative importance of sheep and red deer on impacts within and between regions.

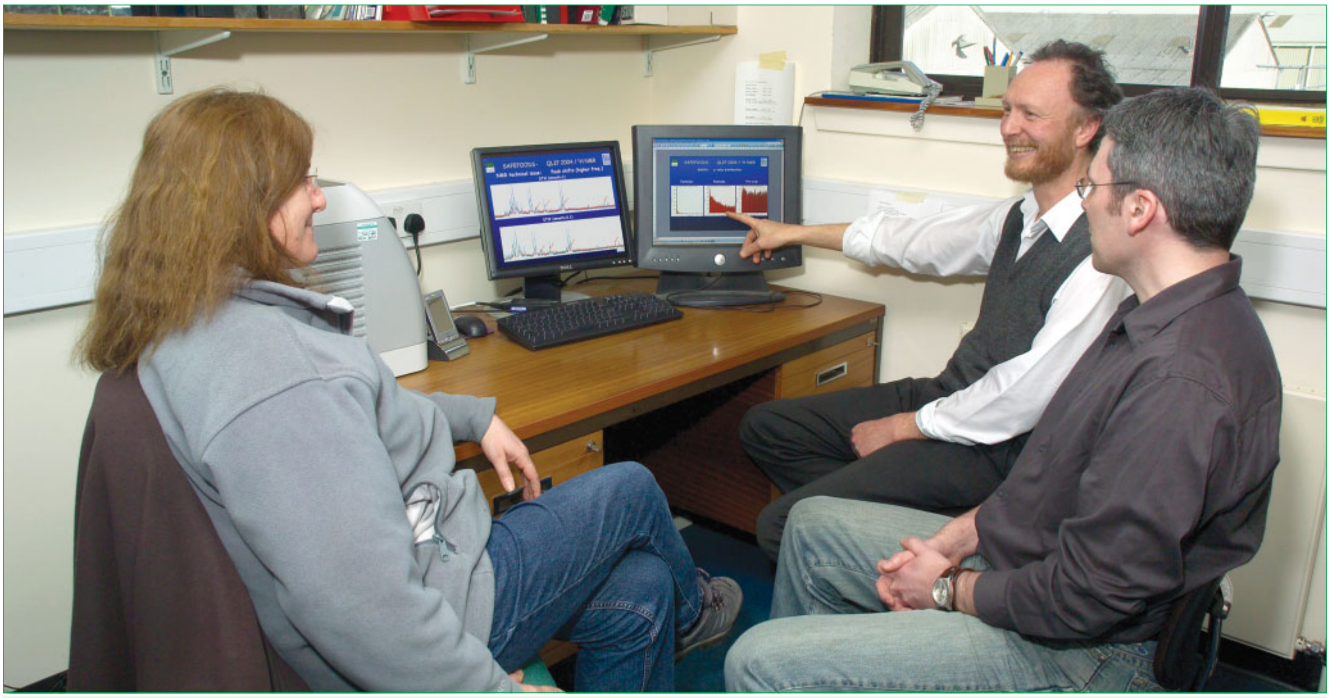
Our consultancy work for human health and nutrition supports scientists investigating chronic dietary-related conditions such as obesity, cardiovascular health and gut health. A recent development is the large amount of proteomic data being generated in order to understand the effects of diet on protein expression, and both univariate and high dimensional multivariate statistical methods are important in efficient interpretation of these data. In gut health research, the use of stable isotopes is important in tracing the metabolic pathways and fluxes of the different products of colonic bacterial activity. BioSS's mathematical and statistical expertise has been instrumental in developing compartmental models and in estimating flow rates from stable isotope data.

BioSS manages its programme of applied strategic research in three broad themes:

- statistical genomics and bioinformatics;
- systems and process modelling;
- statistical methodology.

The research we carry out addresses generic issues encountered in our consultancy work that are not adequately addressed using standard methods. Each research theme is related to each of the four broad scientific areas, demonstrating the wide applicability of BioSS research.

The statistical genomics and bioinformatics research theme addresses a wide range of modelling and data analysis problems that can be grouped under the six headings of genetic association, genomics, transcriptomics, proteomics, metabolomics and regulatory networks. Current scientific efforts to develop more efficient strategies for disease and pest control in crop plants require an understanding of the interaction between signalling pathways in hosts and pathogens. Our work on regulatory networks offers the prospect of improving estimation of sub-cellular interactions, lead-



ing to more effective control of sub-cellular processes, by combining high-throughput postgenomic data, e.g. promoter sequences, gene expression profiles from microarrays, and putative protein–protein interactions. In particular, BioSS has been contributing to the development of statistical methods for the robust inference of sub-cellular regulatory networks in the presence of biological stochasticity and noisy data.

The systems and process modelling research theme consists of methodological activities such as analysis, simplification and approximation of stochastic process models motivated by four classes of applications, namely: modelling large populations in heterogeneous environments; modelling risks to biodiversity in a changing environment; complex interactions in epidemic processes; and Bayesian methods for decision support. This year has seen a particular emphasis on species distribution modelling. One issue addressed by BioSS has been to estimate spatial variation of recorder efforts in species atlas data in order to produce modelled species distributions that are standardised for recorder effort. Another issue addressed by BioSS is the development of spatio–temporal models for the spread of invasive species allowing for environmental heterogeneity and for stochastic colonisation events whose probability decreases with distance from the existing population.

The statistical methodology research theme involves empirical modelling of data that are correlated due to the effects of space and/or time, extracting information from digital images, along with diverse methods such as compositional analysis and latent Gaussian modelling which need developing to resolve problems encountered in our consultancy work. One application arises from the SAC–BioSS CT Unit, which uses X-ray computed tomography to estimate body composition of sheep. This necessitates the positioning of segmentation boundaries on images in order to identify the tissues such as bone, fat and muscle. If images are 2-dimensional, dynamic programming (DP) is a fast, elegant method for achieving this. We have developed a generalisation of DP, a greedy algorithm termed *iterated dynamic programming*, for segmenting 3-dimensional images. The method has been implemented in BioSS's STAR software, and is used routinely in sheep trials.

More details about the work of BioSS, including a wider range of examples of our work and a description of associated knowledge exchange activities and software products, can be found on the BioSS website www.bioss.ac.uk.

Statistical analysis of metabolomic data

Jim McNicol, Susan R. Verrall, Tom Shepherd, Gary Dobson, D. Wynne Griffiths, Gavin Ramsay, Howard V. Davies & Derek Stewart

Metabolic compositional profiles, consisting of hundreds of compound intensities, are increasingly used at SCRI to characterise samples of different genotypic and environmental backgrounds. We illustrate two exploratory statistical analyses using profiles consisting of 78 GC-MS polar and 52 non-polar compounds from 156 potato tuber samples. The mother plants, grown from true seed in a glasshouse, represent the four main cultivated groups of potato within the broad definition of *Solanum tuberosum*, Andigena, Phureja, Stenotomum and Chilean Tuberosum, with 78, 43, 24 and 11 accessions, respectively.

The first approach is to identify the main sources of variation using all 130 compounds. Principal components (PCs) achieve this by partitioning all the variation into uncorrelated variables, the first few of which often summarise broad effects. Interpretation of the principal components is achieved through 'loadings', the relative contributions of each metabolite, and 'scores', the sample values on the components.

Loadings show that the first PC describes total metabolite content and Fig. 1 (a) shows that this is negatively correlated with % dry matter content for each group except Tuberosum. The third PC is dominated by fructose, glucose and sucrose and Fig. 1 (b) suggests that

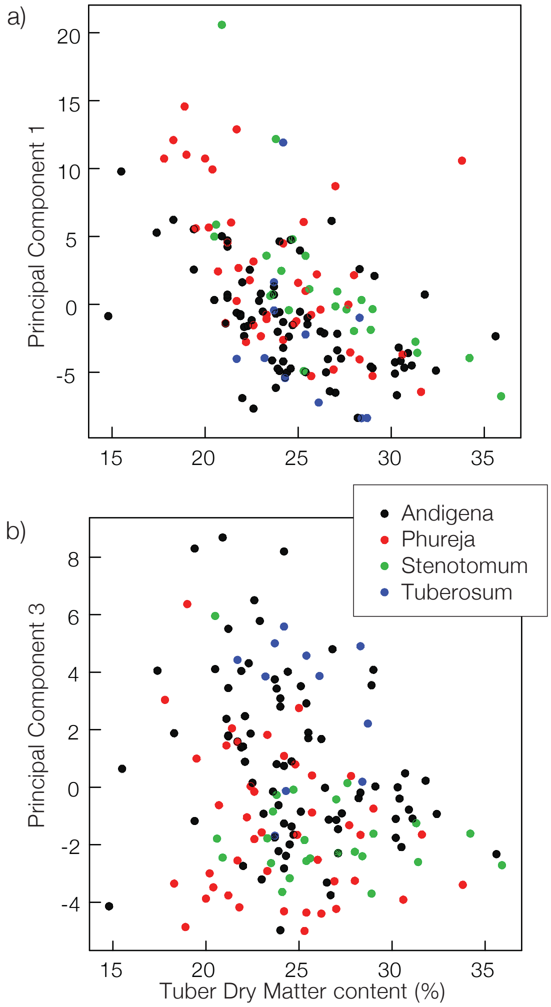


Figure 1 Relationship between principal components and % dry matter (a) PC1 – Total metabolite content (b) PC3 – sugar content.

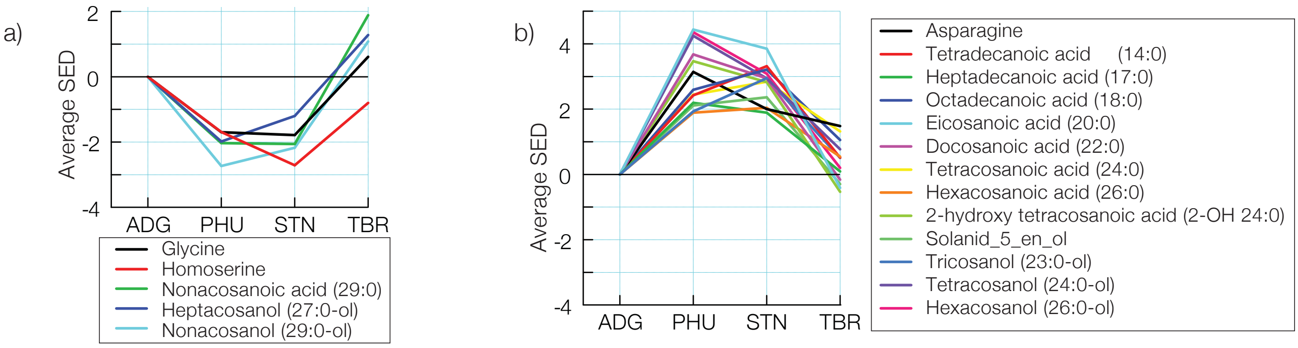


Figure 2 Accumulated expression clusters
(a) predominantly long chain odd-carbon fatty acids and alcohols (b) predominantly even-carbon fatty acid and alcohol homologues.

levels of these sugars are relatively high for Tuberosum and low for Stenotomum.

The second approach identifies individual metabolites which are differentially accumulated among the groups. This is achieved by analysis of variance of each metabolite separately. A significance cut-off corresponding to a false discovery rate of 2% identified 59 metabolites which were accumulated differentially. Hierarchical clustering, based on pairwise standard errors of difference between groups, partitioned these metabolites into groups of similar significance patterns across the four groups.

Three main groups of biosynthetically-related, non-polar metabolites (composed of saturated fatty acids and fatty alcohols) were identified, differing predominantly in the length of their carbon chains and in the presence of chains with odd and even numbers of carbon atoms. It is also of note that unsaturated fatty acids, the major constituents within the non-polar metabolites, do not appear in any of the clusters and therefore do not show any significant inter-group variation. This could reflect differences in the specificity of the enzyme systems responsible for synthesis of long carbon chains, similar to those observed for various leaf lipids (Shepherd, 2003; Shepherd & Griffiths, 2006). Fig. 2 (a) shows the group which includes long chain odd-carbon fatty acids and alcohols, whereas in Fig. 2 (b) the cluster consists mainly of even-carbon fatty acid and alcohol homologues. The different patterns probably reflect the existence of parallel pathways for synthesis of odd and even carbon components, and a shift in the partitioning of precursors between the pathways in Phureja and Stenotomum in comparison with Tuberosum and Andigena.

References

Shepherd, T. 2003. Wax pathways. In: Thomas, B., Murphy, D. & Murray, B. (eds). *Encyclopaedia of Applied Plant Sciences*, Academic Press, London, 1204-1225.

Shepherd, T. & Griffiths D. W. 2006. The effects of stress on plant cuticular waxes. *New Phytologist* **171**, 469-499.

Partnerships and Collaboration

SCRI is committed to developing partnerships and collaborative arrangements with other scientists whenever this will enhance our capacity to undertake excellent research. Many formal and informal collaborations exist, but particular attention has been paid during 2006 to developing appropriate UK and international partnerships.

In the UK, we have been working closely with Rothamsted Research, the Institute of Grassland and Environmental Research, and the John Innes Centre to establish the BBSRC cross institute programme on cereal genetics, MONOGRAM. MONOGRAM's main objectives are to provide infrastructure and resources that will enable basic research to make a significant contribution to innovative approaches to crop genetic improvement, and the consortium has appointed Dr Tina Barsby to manage the programme. The core of the programme will lie in the formation of cross-institute teams to ensure the efficient use of all available tools and resources (e.g. germplasm and markers, transcriptomics, proteomics and metabolomics, and bioinformatics) and to plan for new facilities or major pieces of equipment. Simultane-

ously the programme will make a major effort in physically mapping the wheat, barley and lolium genomes in order to provide the tools and information necessary for gene identification and for alignment with available and emerging model plant genome sequences (e.g. rice and Brachypodium). MONOGRAM plans to establish major research themes in areas such as recombination, bioenergy, disease resistance and the identification of traits for cereal grain quality. In similar vein, the SOIL cross institute programme (with Rothamsted Research and the Institute of Grassland and Environmental Research as founding partners) has invited SCRI to participate in elements of its research programmes, especially those focussed on carbon-derived energy and its relation to soil resilience and function, and the interactions of plant roots with soils to create soil structure. SCRI will engage constructively with these research areas and with the experimental platforms that the programme is seeking to establish.

Internationally, SCRI has signed a series of cooperative agreements with institutes in China, and commenced collaborative projects during 2006. MRS Ltd sent some advanced lines and cultivars of potato for trials to the Chinese Academy of Agricultural Sciences, Institute of Vegetables and Flowers, Beijing, and raspberries were sent to Jilin Agricultural University, Changchun, to add to the blackcurrants already undergoing trials. There is considerable commercial interest in China in developing the potato industry into a major consumer industry and MRS Ltd has been working with other agencies to overcome the ban on imports of microtubers and seed potatoes. Soft fruits for processing into juice are also beginning to develop as a product and, again, MRS Ltd is working to ensure that our varieties are considered for exploitation. Several members of the Institute contributed to a major workshop on root/soil interactions in Nanjing in late May and, during a visit to China in mid-October, Peter Gregory signed agreements with both the Chinese Academy of Sciences, Institute of Soil Science, and Nanjing Agricultural University, both in Nanjing. These agreements will allow the collaborative work on soils to continue and there are plans for further exchanges of research students. While in China, Peter also signed an agreement with Jilin Academy of Agricultural Sciences, Gongzhulin which could lead to SCRI’s expertise on the monitoring of introduced GM crops being extended to northern China. These three new agreements bring to six the number of formal agreements with Chinese institutions.

Research Services

Communication and Information Services The Communications Team is concerned with promoting good relations with stakeholders both within and outwith the Institute. They arrange visits, conferences, exhibitions and events to promote SCRI's scientific research to industry, politicians, the general public and school children. The successes have included industry events such as the SCRI/LEAF open day "Sustainable Agriculture – rsearch from laboratory to field" attended by many farmers and representatives of associated industries and the open days based around the Advanced Higher curricula for biology and chemistry; these were attended by students from 30 schools.

The Visual Aids unit has continued to provide a service in presenting the work of the Institute. Scientific posters were made showing details of SCRI research at conferences throughout the world. 3000 photographs were taken for use in publications and displays during the year and archived for record purposes. The website was restructured and a new content management system was put in place.

The Institute's Library is continuing to make as much electronic information available at scientists' desktops as possible. Subscriptions to electronic bibliographic databases and journals take up the bulk of the budget but there is still scientific literature in print which is housed in the Library.

Information Technology underpins all our computerised information systems, business processes and information requirements. There are approximately 500 PCs on site used as general purpose IT systems (email, word processing, spreadsheets, etc.), specialist computational systems and various network and infrastructure systems, which support and enhance the capability of our technology requirements. The Storage Area Network continues to develop and further increases the data capacity and resilience of the system. Our internet connection is via FATMAN (Fife And Tayside Metropolitan Area Network) which in turn connects us to JANET (UK Joint Academic Network). This year we have moved entirely from Novell Netware to Windows Active Directory, which has allowed us to consolidate our resources on to one platform. A key responsibility for IT is in ensuring secure connections for all information transfer, and this is achieved by the use of firewalls, spam filtering, automated virus checking at all points and automatic patch delivery to systems. In addition to the responsibility for the running of the infrastructure and servers at the Institute, IT is involved in the development of webenabled database applications and portal/workflow enhancements.

Finance and Corporate Services The finance department consists of a small team of six people who provide financial support and advice to research and other activities of the Institute through planning, management, and control of its business operations.

A wide range of activities is undertaken which can be summarised as stewardship, input into the strategic planning process, and transaction processing. There is, in addition, active participation in the Institute's risk assessment procedures.

The department is responsible for putting in place internal control systems that are suitable for the needs of the business and ensuring that these systems, and adherence to them, are reviewed by independent audit. The department's procedures aim to safeguard the assets of the Institute. In addition current practices are continually reviewed to improve value for money.

The department works closely with research and support departments to develop strategic financial and operational plans and provides regular updated forecasts to support decision making processes.

The finance department is responsible for producing financial accounts, including the annual statutory accounts, which comply with current statutory and regulatory obligations, and in addition aims to produce accurate, timely and meaningful management information to enable Institute management to monitor performance against budgets.

The department endeavours to ensure that all income due to the Institute is recorded and received timeously, and that payments to suppliers are accurately made in accordance with targets and guidelines.

Human Resources In 2006 the department developed a new HR Strategy to support the delivery of the SCRI Group Science Strategy 2006 – 2011. During 2006 major pieces of work for the HR department included:

- establishing an HR Committee to provide advice and support to the HR team;
- running a development programme for members of the Senior Management Board including sessions on understanding the corporate role of the SMB and managing change;
- working with the SMB to develop a staffing plan; and
- identifying key topics to be addressed under the Diversity agenda.

The HR department has also been heavily involved in managing the restructure process at SCRI and the appointment of new staff into senior positions during the year.

Health and Safety, Quality Assurance and Environmental Management The results of auditing the integrated management system by external auditors SGS indicated improvements in health and safety, quality assurance and environmental management against the standards OHSAS 18001, ISO 9001:2000 and ISO 14001:2004. There were 19 accident and incident reports over the year, two of these being reported to the Health and Safety Executive under the Reporting of Diseases and Dangerous Occurrences Regulations as they led to work absences of more than three days. Both members of staff are now back at work.

This year staff were given a choice of health and safety objectives to achieve which related to their work. These could involve some form of health and safety training or risk assessment of a task or work area. The success of the scheme will be reviewed following staff appraisals at the end of the year.

Behavioural health and safety training was carried out early in the year for supervisors in the Engineering and Maintenance Department and in Field and Glasshouse Services. Other training has been on the use of abrasive wheels, nail-gun use, first aid, laminar flow cabinet fire safety, manual handling, breathing apparatus team operations and laboratory gas handling. In addition a Safety Day was held which covered basic first aid and topics such as tractor safety, working at height, fire safety and chemical hazards.

A policy of no smoking in any enclosed spaces on the Institute was introduced in accordance with the Smoking, Health and Social Care (Scotland) Act 2005 and associated regulations which came into force on 26th March 2006.

Risk Management is overseen by the Audit Committee of the Governing Body. The remit of the Committee includes the implementation of the Institute's risk policy, ensuring that the Institute has a reliable and comprehensive system of internal control and risk management, as well as encouraging the development of a culture of risk awareness and risk management for all staff.

The Committee is required to review all aspects of risk management, at least annually, to report to the Governing Body upon the efficacy of such systems and to advise the Governing Body upon the Institute's risk policy.

The Committee ensures that the Institute has a comprehensive system of internal control and risk training, determines the principal areas of risk, their likelihood and exposure, in particular those related to the operations and finances of the business, and are satisfied that controls and systems are in place to mitigate the company's exposure to the major risks.

Engineering and Maintenance Department Extensive laboratory administration and ancillary facilities are maintained by the Engineering department who are also responsible for electrical, heating, plumbing, data/telephony cabling, painting and joinery work. In addition major building work undertaken by subcontractors is supervised by the department.

The Institute operates from a site with disparate buildings housing administrative offices, research facilities and storage areas for scientific and farm equipment and plant material including the Commonwealth Potato Collection. The engineering department, in addition to maintaining the estate's building stock, is also responsible for carrying out a programme of refurbishment which continually upgrades laboratories and administrative offices.

Utilities costs are a significant component of the running costs of the Institute and measures have been taken to reduce the Institute's consumption of energy; further efficiency gains will be sought. The Engineering department also undertakes routine maintenance and repairs to scientific equipment to restrict costs.

The department, through its farm workshop, provides a repair and maintenance service to the Institute's fleet of tractors and agricultural machinery.

Estate, Glasshouse and Field Services Among the facilities which distinguish the Institute from other organisations is a comprehensive range of glasshouse and controlled-environment cabinets and rooms. There are approximately 10,000 m^2 of glasshouse facility available, ranging from cold glasshouses to sophisticated containment glasshouses with associated laboratories. In addition, the Institute has 13,000 m^2 of polytunnels and net structures. Staff provide a support service to the scientific community throughout the year and are responsible for the production of consistent, high quality plant material under a large variety of experimental regimes. The provision of these facilities is made possible as a result of capital grant from the SEERAD. The Institute has a meteorological site where data are collected for use by the Meteorological Office, SCRI scientists and the local community.

Ruth McHutcheon, who is studying for a degree at Writtle College in Essex, spent 42 weeks working in the glasshouse on industrial placement. Her work included a study on the use of Dundee's green-waste "Discovery" compost as a partial peat replacement in the SCRI compost mix.

The area available to conduct a wide range of agricultural, horticultural and environmental trials remains at about 175 ha despite the loss of some land at Gourdie Farm to the Western Gateway Housing Development. This has been compensated for by the lease of adjacent land at Pilmore Farm. An expert service is provided in

relation to land preparation, sowing, drilling, harvest and clearance of residues. In addition to being responsible for the production of annual crops such as potatoes, brassicas and cereals, field staff also maintain the Institute's 10 ha of perennial soft fruit trials.

As part of the ongoing maintenance of the infrastructure, emphasis has been given to improving the biodiversity of the Institute in line with the objectives of Linking Environment And Farming (LEAF). A large *Leylandii* hedge has been removed and extensive repair work carried out to the adjacent drystone dyke. Individual hardwood trees and a new mixed native hedge have been planted. Prior to the successful LEAF Open Day held in May, additional display boards were erected at strategic points along the extensive public pathway system.

Spring barley is grown extensively as a break crop to remove the footprint of previous field trials, especially perennials such as soft fruit. The harvested grain is sold through the Scottish Quality Cereals Scheme. Part of this quality assurance scheme requires the Institute to follow the aims of the Voluntary Initiative to minimise the impact of pesticides on the environment. All spray equipment is inspected regularly and all staff are registered.

An additional 0.13 ha has been added to the Living Field Community Garden to encompass the growing of rare arable weed species. This educational resource continues to develop the links between schools, science and agriculture.

The Staff Association has been very active providing social events for all staff and raising money through many of the events for the nominated charities.

The successful seasonal events that were held included the Christmas Fayre, lunch, disco, meal and summer barbecue. Two events were revived after an absence of several years, the young children's Christmas party in the canteen, and the ceilidh in November at the Hilton hotel.

The Association gives support to the golf, fishing, hill walking, and football fraternities along with the Corporate Sports membership at Dundee University. There are Yoga, Keep Fit, Salsa, Indian head massage, and Tai Chi sessions.

Members' benefits include entry into a monthly draw to win meal and cinema vouchers. There is use of National Trust cards and a Booker cash and carry card. A subscription to "Which" magazine is provided for members in the SCRI library and is available to access online. Members are offered 25% off the full cost of any event/activity when they participate. Subscription fees remain at £1.50 per month and membership, currently around 200, is open to anyone working at SCRI. Any individual who has maintained membership for 10 years or more and leaves is entitled to a £25 cheque. Members select the charities each year. For 2005/6, three charities received £415 each. They are, Dundee Blind and Partially Sighted, Dundee Women's Aid and Menzieshill Community Centre.

Postgraduate Studentship Programme

David F. Marshall, Gary D. Lyon & Alison G. Roberts

SCRI has developed a thriving postgraduate research programme which offers a broad range of training opportunities to students from the UK, the EU and the rest of the world. The research environment at SCRI is unique in that it covers the full scope of plant and environmental studies from fundamental to more applied aspects. Our research, therefore, has impact on the academic science base as well as on both commercial companies and policy makers. This breadth enables postgraduate students to be exposed to a broad range of plant, crop and environmental science and thereby to place their own more focussed research into context. This is an extremely valuable component of their overall training.

The primary aim of the postgraduate training provided by SCRI is to equip the individual students with a wide range of modern scientific skills whilst developing technical and intellectual competence that can be applied in a range of scientific careers. Delivery of this training and personal development is sensitively monitored and supported to ensure that each individual student achieves the highest standards of intellectual flexibility, whilst presenting a comprehensive range of scientific and transferable skills demanded by today's employers of trained scientists. Past graduates are to be found as far afield as research organisations in Australia, Kenya and the USA as well as making a major contribution to the research base of Scotland and the UK. Indeed some have gone on to become valued colleagues and collaborators.

Students at SCRI are registered at a number of universities across the UK, depending on funding sources and the need to identify university supervisors with the necessary scientific skills and knowledge. However, a significant proportion of our students are locally registered at the University of Dundee with whom SCRI has established a partnership embodied by the location of the University of Dundee Plant Science Unit on the SCRI campus. The relationship with the University of Dundee also includes a special arrangement whereby all postgraduate students at SCRI, independent of the university at which the student is registered, have access to and can use the facilities available at the University of Dundee, including English language tuition, training courses, library, scientific facilities and counselling.

A major new feature of SCRI's postgraduate training for the 2006/2007 academic year has been the creation of a new Joint Studentship Programme with UK Universities. This Programme is aimed at developing new collaborative links and interactions with university groups across the country, and, in particular, with Scottish Universities. The second round of studentships, to begin in

2007, is currently underway and there will eventually be up to 30 jointly funded students. The Programme represents a major investment in training scientists of the future who will play key roles in developing the science that will be required to meet major challenges such as global warming and loss of biodiversity. This commitment also reflects the valuable role that each new cohort of postgraduate students plays in bringing 'new blood' to stimulate the research environment across the Institute. The new scheme has also provided exciting opportunities to broaden our existing science base by, for example, combining the expertise in the chemistry and biochemistry of plant compounds at SCRI with diet and health expertise in university research groups in new multi-disciplinary areas of science.

In addition to students funded under the Joint Studentship Programme SCRI has students funded through a diverse mix of grants, contracts and studentships and we welcome enquires from overseas applicants funded by their own government schemes. We particularly value this diversity and in turn students find working in Dundee brings many benefits. These include a "high quality of life" that comes from living in a location with excellent access to beautiful countryside and the facilities of all Scotland's cities.

The Scottish Society for Crop Research

Bill Macfarlane Smith

Trustees:
Professor J.R. Hillman
Mr I.E. Ivory
Mr A. Logan
Mr J.S. Whitehead

Chairman: Dr S. Wale

Vice- Chairman: Mr A. Redpath

Committee of Management:
Dr K. Dawson
Professor J.R. Hillman
Mr I.E. Ivory
Mr A. Logan
Mr L.M. Porter
Mr J.S.Whitehead

Secretary: Dr W.H. Macfarlane Smith

Treasurer: Dr N. Hattersley

Registered Office: c/o Scottish Crop Research Institute,
Invergowrie, Dundee, DD2 5DA.

Membership Numbers: 240

The Society provides a link between SCRI and farmers, processors and other interested bodies:

- by organising field walks and meetings for the exchange of information
- by financing science-based publications for the benefit of the membership
- through the formation of crop-based sub-committees which maintain contact with members on specialised topics
- by funding research at SCRI which is either 'pump-priming' to initiate new research, or work for minority interests that the large funding bodies would not support

The Society continues to support research work on wheat blends and low input production, and the production of a soft fruit pathogen database. Work on a quantitative detection method for potato cyst nematode is being funded and financial support was provided for a speaker at the Crop Protection Northern Britain Conference. Ongoing support is being provided for the consortium producing new varieties of raspberry and will continue until 2009.

The Annual General Meeting was held on 30th May 2006, after which the SSCR Lecture was given jointly by Professor Steve Parry of Unilever, entitled 'Sustainable Agriculture – A Food Manufacturer's Approach from Field to Fork',and Dr Keith Dawson of SAC, entitled 'Scottish Arable Farming – Is There a Future?'.

The Society has a particular interest in Knowledge Transfer, which it achieves through crop events, which are open to the general public as well as members, and half day technical meetings.

Of the former, 'Cereal Solutions', was held on 7th July 2006 and attracted 49 visitors to a further expanded range of demonstrations, including genetic markers, cereal mixtures and potential varieties of wheat for use by the distilling industry. A demonstration of quality factors in whisky was provided by Dr James Brosnan of the SWRI.

The Fruit for the Future event was held on 20th July 2006, and attracted 84 breeders, growers, end-users and processors, so more than doubling the previous year's attendance. The latest research on raspberries, strawberries, blackcurrants and other soft fruits was displayed. Prospective new varieties of raspberry and strawberry were available for tasting assessment, with special interest in the former, showing their potential when grown in polythene tunnels.

‘Potatoes in Practice’, the potato event supported by the Society, the British Potato Council, the Scottish Agricultural College, CSC Crop Protection Ltd., and SCRI, was held on 10th August 2006. The event attracted 530 visitors, again a considerable increase on the previous year's attendance. A wide range of demonstrations included new varieties, the history of the potato and new machinery. It is now recognised as the predominant outdoor potato event in the UK.

The occasion was also taken to present the Peter Massalski Prize. This very generous award was provided by Professor T B and the late Mrs Massalski in memory of their son Peter. It is awarded every second year to the outstanding scientist under the age of 36 working at SCRI, and is administered by the Society. The 2006 award was made to Dr Alison Lees for her work on the development of methods for detecting potato pathogens and for improving understanding of the epidemiology of potato diseases. The presentation was made by Dr Stuart Wale, Chairman of the Society.

The Society continues to grow in size, with a number now taking advantage of the new category of Life Membership at a cost of £100. The Committee of Management is keen to encourage growers and processors to join the Society and to participate not just in the various crop-based meetings but also in the management of the Society and its various Sub-Committees.

Mylnefield Research Services

Nigel W. Kerby & Jonathan B. Snape

MRS, the commercial wholly-owned subsidiary of SCRI, was established in 1989 to enhance competitiveness, understand and fulfil the needs of industry and maximise the value of SCRI intellectual property and resources. MRS has grown steadily and continued to benefit SCRI through annual Gift Aid and provision of services, without any external financial assistance.

The Mission Statement of MRS is:

To develop commercially the SCRI' s scientific expertise, resources and intellectual property, and to improve the quality of services to achieve new standards of excellence.

Finances The income of MRS increased to £1.99 million in 2005/2006 and MRS transferred £1.32 million to the SCRI Group, including £90K Gift Aid to the Mylnefield Trust and £125K Gift Aid to SCRI. This represents an increase of 63% on previous year's Gift Aid. Contract research (66%) was the biggest contributor to income, followed by lipid analysis (15%) and royalties (10%).

Innovation MRS values its industrial partnerships since they provide valuable market and technical information for the science programmes at SCRI in addition to cost effective product development.

Commercial research collaborations MRS develops long-term research collaborations with commercial partners through various schemes, including LINK projects. Currently MRS is involved in six LINK projects at SCRI:

- Developing molecular markers for raspberry root rot with the Horticultural Development Council (HDC).
- Developing molecular markers for raspberry quality with the HDC, Marks and Spencer plc, KG Growers Ltd, Thomson and Thomson Ltd and Redeva Ltd.
- Understanding the chemistry and genetics of potato flavour with the British Potato Council, Greenvale AP, Branston Ltd, BioSS and Sensory Scotland Ltd.
- Integrated pest management for raspberries with the HDC, KG Growers Ltd, Bayer Crop Science Ltd, Waitrose Ltd, Cooperative Group Ltd., Berryworld Ltd., British Polythene Industries Ltd. and East Malling Research (EMR).
- Barley association genetics with 12 commercial partners including Syngenta Seeds, Coors Brewers, Svalöf Weibull and the Scotch Whisky Research Institute
- Improving the Vitamin C levels in blackcurrant with GlaxoSmithKline plc, EMR and the HDC.

Licensing and IP asset management Our IP portfolio is dominated by plant variety rights (55) but also includes five patents and five trademarks. We currently manage 490 licenses in 23 countries for potatoes, forage and salad rape, turnip, kale, blackcurrants, blackberry, raspberry and strawberry varieties. Varieties bred at SCRI are being trialled all over the world including Japan, China, Romania, Australia, Cuba and Egypt.

During 2006, MRS started collecting royalties for the production of Glen Lyon raspberries (380 hectares) in southern Spain. Glen Lyon is the number one variety in Spain. Success resulted from our close collaboration with our agents Eurosemillas as well as UK multiple retailers, importers, propagators and the Spanish legal system. We are introducing new varieties into this important rewarding market. Spanish raspberry production complements that of the UK since it provides fruit to the UK consumer out of season.

New varieties Mayan Gold was launched in autumn 2006 by our partner Greenvale AP into two UK supermarkets. This was the first time a variety of *Solanum tuberosom* Group Phureja, also known as *S. phureja,* was available to consumers and the launch received considerable national publicity.

Since 2003 a consortium, including SEERAD and MRS, has been investing in the development of new and superior raspberry cultivars. In July 2006 at 'Fruit for the Future' we launched the first variety (Glen Doll) from this programme.

Glen Doll

The swede Lomond was launched by our partners Nickerson Advanta Ltd at a trade show in Edinburgh during November 2006.

Analytical services Mylnefield Lipid Analysis increased its business and held a successful workshop on omega-3 fatty acids in June 2006. A two day lecture course was held in October 2006 that attracted participants from a wide range of commercial and academic backgrounds.

MRS, together with Dr Charlie Scrimgeour of SCRI, offers a stable isotope analysis service. This business has grown significantly in recent years and is now a major contributor to turnover of MRS.

Developing markets In March 2006, MRS led an Agricultural Trade Mission, organised by the China Britain Business Council (CBBC), to China and continued to concentrate its efforts on developing the Chinese potato and soft fruit markets. MRS has played a significant role in facilitating the lifting of the export ban on UK seed potatoes to China – a bilateral trade agreement was signed in October 2006 for the export of UK mini-tubers to China.

In October 2006 the SCRI director, Professor Peter Gregory, accompanied Dr Nigel Kerby to China where a further three Memoranda of Understanding (MoU) were signed with Chinese research organisations in the fields of environmental monitoring, plant and soil interactions and soil resilience.

MRS was invited to join a ministerial Agri-Food Trade Mission to India (March 2006) to stimulate trade in the agri-food sector between India and the UK. India has more irrigated agricultural land than any other country in the world, is the world's second largest producer of potatoes and fruits and a major producer of barley, so offers significant opportunities for SCRI's expertise and products. As a result of the mission, two proposals for funding with the Central Potato Research Institute in Shimla have been submitted and other opportunities for collaboration identified in the areas of plant health, horticulture, micropropagation and barley breeding.

Knowledge transfer and exploitation

- MRS successfully coordinated a bid, on behalf of SCRI, with five other research institutes for £2.5 million of seed funding from the Office of Science and Technology to add to the £6 million Rainbow Seed Fund. MRS and SCRI now have access to seed funds for developing innovative products and services.
- MRS, with Dundee and Abertay Universities and Dundee, Angus and Perth Colleges of Higher Education, established Tayside Knowledge Transfer Partnership with support from Scottish Enterprise Tayside.
- In August 2006, the Dundee SME Innovation Portal was awarded £406k from the Scottish Executive SEEKIT programme as well as £198k ERDF funding. This new initiative brings together MRS (on behalf of SCRI), the two local universities, Scottish Enterprise Tayside and Dundee University Incubator Ltd.
- In December 2006, MRS was awarded £180k from the Scottish Executive SEEKIT programme to enable Interface to extend its remit to include research institutes as well as universities. Interface provides a one-stop shop for companies wishing to access expertise and facilities available in Scotland.

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. We would like to thank the non-executive Directors of MRS who contribute their valuable time without recompense.

Mylnefield Trust and Mylnefield Holdings Ltd

The Mylnefield Trust and Mylnefield Holdings Ltd (MHL) were established in 2000 in order to give the SCRI Group the flexibility it requires to grow. Central to this growth is the creation of a number of spin-out companies, such as Scottish Potato Technology Ltd, in which MHL on behalf of the SCRI Group will hold equity.

The Trust currently has funds of approximately £400K, achieved mainly through donations from MRS Ltd.

The Trust has charitable status and has as its prime objectives:

- to promote research and scientific work in the life, environmental and related sciences, in particular production of agricultural, horticultural and forestry crops, methods of limiting or eradicating pests and diseases, wood sciences and biomathematics, methods of increasing production or growth, improving cultivation and research into possible varieties.
- to promote the dissemination of such research.

To date the Trust has financially supported:

- a Research Incentive Fund;
- an Educational Officer at SCRI;
- a hardship fund for an overseas student;
- various research projects valued at £48,751.

During the financial year 2006-07 The Mylnefield Trust is supporting three projects amounting to £7,552. Also during this financial year The Mylnefield Trust is supporting scientific publications up to a value of £10,000.

Publications for the year 2006

Publications are classified in the following manner:

J	Papers describing original research in refereed journals.
R	Critical reviews in journals, 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).
T	Technical reports, other publications.
O	Popular articles, other publications.

Aalders, L.T., Bell, N.L., Barratt, B.I.P. & Neilson, R. 2006. Using expatriate New Zealand flora as predictors of nematode threats to New Zealand natural ecosystems. *European Society of Nematologists Biennial Meeting,* Blagoevgrad, Bulgaria, 5–9 June 2006. P

Adam, M.A.M., Phillips, M.S., & Blok, V.C. 2006. Comparisons of pathogenicity factors from mi virulent and avirulent *Meloidogyne javanica*. *European Society of Nematologists Biennial Meeting*, Blagoevgrad, Bulgaria, 5–9 June 2006. P

Abang, M., Baum, M., Ceccarelli, S., Grando, S., Linde, C.C., Yahyaoui, A.H., Zhan, J. & McDonald, B.A. 2006. Pathogen evolution in response to host resistance genes: Evidence from field experiments with *Rhynchosporium secalis* on barley. *Phytopathology,* **96**, S2. P

Andersen, H.S., Gambling, L., Holtrop, G. & McArdle, H. J. 2006. Maternal iron deficiency identifies critical windows for growth and cardiovascular development in the rat postimplantation embryo. *Journal of Nutrition* **136**, 1171–1177. J

Andow, D.A., Birch, A.N.E., Dusi, A.N., Fontes, E.M.G., Hilbeck, A., Lang, A., Lövei, G.L., Pires, C.S.S., Sujii, E., Underwood, E. & Wheatley, R.E. 2006. Non-target and biodiversity ecological risk assessment for GM crops. *International Society for Biosafety Research. Ninth International Symposium on Biosafety of Genetically Modified Organisms,* Jeju Island, Korea, 24–29 September 2006. P

Andow, D.A., Fontes, E.M.G., Hilbeck, A., Johnston, J., Capalbo, D.M.F., Nelson, K.C., Underwood, E., Fitt, G.P., Sujii, E.R., Arpaia, S., Birch, A.N.E., Pallini, A. & Wheatley, R.E. 2006. Supporting risk assessment of *Bt* cotton in Brazil: synthesis and recommendations. In: Hilbeck, A., Andow, D.A. & Fontes, E.M.G. (eds). *Environmental Risk Assessment of Genetically Modified Organisms Volume 2: Methodologies for assessing Bt cotton in Brazil.* CABI Publishing, Wallingford, UK, 346–361. R

Atkinson, C.J., Sunley, R.J., Jones, H.G., Brennan, R. & Darby, P. 2005. Defra desk study on winter chill in fruit. *Defra Report No.* **CTC0206**. T

Bailey, T.C., Carvalho, M.S., Lapa, T.M., Souza, W.V. & Brewer, M.J. 2005. Modeling of under-detection of cases in disease surveillance. *Annals of Epidemiology* **15**, 335–343. J

Barker, H. & Dale, M.F.B. 2006. Resistance to viruses in potato. A consideration of mechanism, genes and seeding techniques. In: Loebenstein, G. & Carr, J.P. (eds). *Natural Resistance Mechanisms of Plants to Viruses.* Springer, Berlin, 341–366. R

Belenguer, A., Duncan, S.H., Calder, A.G., Holtrop, G., Louis, P., Lobley, G.E. & Flint, H.J. 2006. Alternative mechanisms of metabolic cross-feeding between human gut bacteria. *Reproduction Nutrition Development* **46 (Suppl. 1)**, S43. P

Belenguer, A., Duncan, S.H., Calder, A.G., Holtrop, G., Louis, P., Lobley, G.E. & Flint, H.J. 2006. Two routes of metabolic cross-feeding between *Bifidobacterium adolescentis* and butyrate-producing anaerobes from the human gut. *Applied and Environmental Microbiology* **72**, 3593–3599. J

Bengough, A.G. 2006. Principles of Soil and Plant Water Relations. By M. B. Kirkham. Amsterdam: Elsevier Academic Press (Book Review). *Experimental Agriculture* **42,** 123. O

Bengough, A.G., Bransby, M.F., Hans, J., McKenna, S.J., Roberts, T.J. & Valentine, T.A. 2006. Root responses to soil physical conditions; growth dynamics from field to cell. *Journal of Experimental Botany* **57**, 437–447. J

Bierman, S., Fairbairn, J.P., Petty, S.J., Elston, D.A., Tidhar, D. & Lambin, X. 2005. Changes over time in the spatiotemporal dynamics of cyclic populations of field voles (*Microtus agrestis* L.). *American Naturalist* **167**, 583–590. J

Birch, A.N.E., Griffiths, B.S., Caul, S., Thompson, J., Heckmann, L.H. & Krogh, P.H. 2006. A review of the utility of multispecies testing of GM plants in mesocosm experiments. *10th International Conference on Agricultural Biotechnology: Facts, Analysis and Policies,* Ravello, Italy, 29 June–2 July 2006. P

Birch, A.N.E., Wheatley, R.E., Anyango, B., Arpaia, S., Capalbo, D.M.F., Getu Degaga, E., Fontes, E.M.G., Kalama, P., Lelman, E., Lövei, G., Melo, I.S., Muyekhof, F., Ngi-Song, A., Ochieno, D., Ogwang, J., Pitelli, R., Schuler, T., Sétamou, M., Sithanantham, S., Smith, J., Van Son, N., Songa, J., Sujii, E., Tan, T.Q., Wan, F.-H. & Hilbeck, A. 2004. Biodiversity and non-target impacts: a case study of *Bt* maize in Kenya. In: Hilbeck, A. & Andow, D.A. (eds). *Environmental risk assessment of Genetically Modified Organisms Volume 1: A case study of Bt maize in Kenya.* CABI, Wallingford, UK, 117–185. R

Birch, P.R.J. 2006. Using pathogen genomics to investigate the induction and manipulation of inducible plant disease resistance. *Breeding for Inducible Resistance against Pests and Diseases. Proceedings of IOBC/WPRS Joint Working Group Meeting,* Heraklio, Crete, 27–29 April 2006, 20. P

Blok, V.C., Pylypenko, L.A. & Phillips, M.S. 2006. Aspects of population virulence in *Globodera pallida*. *European Society of Nematologists Biennial Meeting,* Blagoevgrad, Bulgaria, 5–9 June 2006. P

Blok, V.C., Pylypenko, L.A. & Phillips, M.S. 2006. Developing tools to predict the behaviour of populations of the potato cyst nematode. *Proceedings of Crop Protection in Northern Britain,* Dundee, 28 February–1 March 2006, 273–278. P

Boag, B. & Neilson, R. 2006. Impact of New Zealand flatworm on agriculture and wildlife in Scotland. *Proceedings of Crop Protection in Northern Britain,* Dundee, 28 February–1 March 2006, 51–56. P

Boag, B. & Neilson, R. 2006. Seasonal fluctuations and long term trends in New Zealand flatworm numbers in Scotland. *British Ecological Society Annual Meeting,* Oxford, 5–7 September 2006. P

Boag, B., Jones, H. & Neilson, R. 2006. The status of the New Zealand flatworm *Arthurdendyus triangulatus* in Great Britain. *10th International Symposium on Flatworm Biology,* Innsbruck, Austria, 29 July–3 August 2006. P

Boevink, P. & Oparka, K. 2005. Virus–host interactions during movement processes. *Plant Physiology* **138**, 1815–1821. J

Bohanec, M., Žnidaršic, M., Griffiths, B.S., Cortet, J., Debeljak, M., Caul, S., Thompson, J., Krogh, P.H. 2006. A qualitative multi-attribute model for the assessment of impact of GM crops to soil quality. *10th International Conference on Agricultural Biotechnology: Facts, Analysis and Policies,* Ravello, Italy, 29 June–2 July 2006. P

Booth, E.J., Bingham, I., Sutherland, K.G., Allcroft, D.J., Roberts, A.M.I., Elcock, S. & Turner, J. 2005. Evaluation of factors affecting yield improvement in oilseed rape. *HGCA Research Review* **53**. T

Booth, E.J., Bingham, I., Sutherland, K.G., Allcroft, D. J., Roberts, A.M.I., Elcock, S. & Turner, J. 2006. Factors affecting yield improvement in oilseed rape. *Proceedings of Crop Protection in Northern Britain,* Dundee, 28 February–1 March 2006, 273–278. P

Bradshaw, J.E. & Birch, P.R.J. 2006. Breeding potatoes for resistance to late blight. *Proceedings of Crop Protection in Northern Britain,* Dundee, 28 February–1 March 2006, 249–254. P

Bradshaw, J.E. & Dale, M.F.B. 2006. Potato Breeding in the 21st century. *Aspects of Applied Biology 76,* Cambridge, 15–16 December 2005. P

Bradshaw, J.E., Bryan, G.J. & Ramsay, G. 2006. Genetic resources (including wild and cultivated *Solanum* species) and progress in their utilisation in potato breeding. *Potato Research* **49**, 49–65. J

Bradshaw, J.E., Bryan, G.J., Lees, A.K., McLean, K. & Solomon-Blackburn, R.M. 2006. Mapping the *R10* and *R11* genes for resistance to late blight (*Phytophthora infestans*) present in the potato (*Solanum tuberosum*) R-gene differentials of Black. *Theoretical and Applied Genetics* **112**, 744–751. J

Bransby, M.F., Davies, M.C.R., Mickovski, S.B., Sonnenberg, R., Bengough, A.G. & Hallett, P.D. 2006. Stabilisation of slopes by vegetation reinforcement. *International Conference on Physical Modelling in Geotechnics,* Hong Kong, 4–6 August 2006. P

Brewer, M.J. 2006. Variable smoothing in Bayesian spatial modelling. *International Workshop on Spatio-temporal Modelling (METMA3),* Escuela Universitaria de Estudios Sanitarios, Pamplona, Spain, 27–29 September 2006. P

Brierley, J.L., Stewart, J.A., Wale, S.J., Hilton, A.J. & Lees, A.K. 2006. Improving decision making for the management of potato diseases. *Proceedings of Crop Protection in Northern Britain,* Dundee, 28 February–1 March 2006, 267–272. P

Brown, J.W.S., Shaw, P.J., Shaw, P. & Marshall, D.F. 2005. Arabidopsis nucleolar protein database (AtNoPDB). *Nucleic Acids Research* **33**, D633–D636. J

Brown, L.E., Hannah, D.M., Milner, A.M., Soulsby, C., Hodson, A.J. & Brewer, M.J. 2006. Water source dynamics in a glacierized alpine river basin (Taillon-Gabiétous, French Pyrénées). *Water Resources Research* **42**, W08404. J

Bruggmann, R., Buchan, D., Abbott, J., Butcher, S., Nicholson, C., McLaren, K., Humphray, S., Rogers, J., Bryan, G., Seymour, G., Bishop, G., & Mayer, K.F.X. 2006. Annotation tools and annotation in the UK tomato chromosome 4. *International Solanaceae Conference and Solanaceae Genomics Network,* Madison, Wisconsin, 23–27 July 2006. P

Bruneau, P.M.C., Davidson, D.A., Grieve, I.C., Young, I.M. & Nunan, N. 2005. The effects of soil horizons and faunal excrement on bacterial distribution in an upland grassland soil. *FEMS Microbiology Ecology* **52**, 139–144. J

Bryan, G., McLean, K., Ramsay, G., Waugh, R., & Spooner, D. 2006. Levels of intra-specific AFLP diversity in tuber bearing potato species with different breeding systems and ploidy levels. *International Solanaceae Conference and Solanaceae Genomics Network,* Madison, Wisconsin, 23–27 July 2006. P

Bünger, L., Lambe, N.R., Navajas, E., Glasbey, C.A., McLean, K.A., Rampersad, M., Lombardi, A., Simm, G. & Macfarlane, J.M. 2005. *In vivo* measurements of body composition in sheep and mice by computed tomography. *Proceedings of the 10th ACERO Symposium on Dietary Approaches to Weight Control*, Aberdeen. 23–24 September, 2005. P

Cacciola, S.O., Chimento, A., Pane, A., Cooke, D.E.L. & Magnano di San Lio, G. 2005. Root and foot rot of Lantana caused by *Phytophthora cryptogea*. *Plant Disease* **89**, 909. J

Cacciola, S.O., Pane, A., Cooke, D.E.L., Raudino, F. & Magnano di San Lio, G. 2006. First report of brown rot and wilt of fennel caused by *Phytophthora megasperma* in Italy. *Plant Disease* **90**, 110. J

Canto, T., Uhrig, J.F., Swanson, M.M., Wright, K.M. & MacFarlane, S.A. 2006. Translocation of the *Tomato bushy stunt virus* P19 protein into the nucleus by ALY proteins compromises its silencing suppressor activity. *Journal of Virology* **80**, 9064–9072. J

Castelli, L., Bryan, G.J., Blok, V.C., Ramsay, G., Sobczak, M., Gillespie, T. & Phillips, M.S. 2006. Investigations of *Globodera pallida* invasion and syncytia formation within roots of the susceptible potato cultivar Désirée and resistant species *Solanum canasense*. *Nematology* **8**, 103–110. J

Caul, S., Griffiths, B.S., Thompson, J. & Krogh, P.H. 2006. Ecotoxicological testing of single species of nematode and protozoa in the laboratory. *10th International Conference on Agricultural Biotechnology: Facts, Analysis and Policies,* Ravello, Italy, 29 June–2 July 2006. P

Chepstow-Lusty, A., Winfield, M., Wallis, J. & Collins, A. 2006. The importance of local tree resources around Gombe

National Park, Western Tanzania: implications for humans and chimpanzees. *Ambio* **35**, 124–129. J

Chloupek, O., Forster, B.P. & Thomas, W.T.B. 2006. The effect of semi-dwarf genes on root system size in field-grown barley. *Theoretical and Applied Genetics* **112**, 779–786. J

Cooke, D.E.L., Williams, N.A., Sullivan, L. & Lees, A.K. 2006. Using SSR markers to investigate Scottish populations and the epidemiology of late blight. *Proceedings of Crop Protection in Northern Britain,* Dundee, 28 February–1 March 2006, 353–358. P

Cortet, J., Andersen, M.N., Caul, S., Griffiths, B.S., Joffre, R., Lacroix, B., Sausse, C., Thompson, J. & Krogh, P.H. 2006. Decomposition processes under *Bt* (*Bacillus thuringiensis*) maize: results of a multi-site experiment. *Soil Biology & Biochemistry* **38**, 195–199. J

Cortet, J., Bohanec, B., Znidarsic, M., Debeljak, M., Griffiths, B.S., Caul, S., Thompson, J. & Krogh, P.H. 2006. A decision support system based on soil ecological criteria: results from the European ECOGEN project.*18th World Congress of Soil Science,* Philadelphia, USA, 9–15 July 2006. P

Cortet, J., Griffiths, B.S., Caul, S., Thompson, J., Tabone, E. & Krogh, P.H. 2006. Effects of transgenic *Bt* corn on microarthropods in a European multi-site experiment. *10th International Conference on Agricultural Biotechnology: Facts, Analysis and Policies,* Ravello, Italy, 29 June–2 July 2006. P

Cowan, G.H., Gillespie, T., Haupt, S., Ziegler, A., Roberts, A.G. & Torrance, L. 2006. *Potato mop-top virus* utilises the endocytic machinery and chloroplasts during replication and movement. *International Symposium on Applications of Plant Sciences in Emerging Scenario,* Faisalabad, Pakistan, 20–22 March 2006. P

Cullen, D.W., Toth, I.K., Pitkin, Y., Boonham, K., Walsh, I., Barker, I. & Lees, A.K. 2005. Use of quantitative molecular diagnostic assays to investigate Fusarium dry rot in potato stocks and soil. *Phytopathology* **95**, 1462–1471. J

Dale, M.F.B., Bradshaw, J.E., Lees, A.K. & Kerby, N.W. 2006. Potato breeding and disease diagnostic developments to improve storage and quality of potatoes to meet industry demands. *Proceedings of Crop Protection in Northern Britain,* Dundee, 28 February–1 March 2006, 243–248. P

Dale, M.F.B., Blok, V.C., Pylypenko, L.A., McLean, K. & Bryan, G. 2006. SNP markers for evaluating copy number of H1 PCN resistance gene in potato breeding germplasm. *International Solanaceae Conference and Solanaceae Genomics Network,* Madison, Wisconsin, 23–27 July 2006. P

Dale, M.F.B., Robinson, D.J. & Wishart, J. 2006. Development of diagnostic procedures to assess the distribution of *Tobacco rattle virus* in fields. *Proceedings of Crop Protection in Northern Britain,* Dundee, 28 February–1 March 2006, 279–284. P

Dale, M.F.B., Robinson, D.J. & Wishart, J. 2006. Diagnostic procedures to assess the distribution of *Tobacco rattle virus* in the UK. *International Solanaceae Conference and Solanaceae Genomics Network,* Madison, Wisconsin, 23–27 July 2006. P

Daniell, T.J., Mitchell, S.M., Davidson, J.A. & Wheatley, R.E. 2006. Nitrifiers in space and time. *11th International Symposium on Microbial Ecology,* Vienna, Austria, 20–25 August 2006. P

Davies, H.V. 2006. Metabolomics: Applications in functional biodiversity analysis in potato. *International Solanaceae Conference and Solanaceae Genomics Network,* Madison, Wisconsin, 23–27 July 2006. P

Davies, H.V. & Sweet, J. 2006. Risk assessment of plants containing genetic modification events combined by crossing: the EFSA approach. *International Society for Biosafety Research, 9th International Symposium on Biosafety of Genetically Modified Organisms,* Jeju Island, South Korea 24–29 September 2006. P

Dawson, L.A., Murray, P.J., Vaisanen, R.K., Duff, E.I. & Ross, J.M. 2005. Soil nutrient supply and herbivory influence grass root longevity. *International Plant Nutrition Colloquium*, Beijing, China, 14–19 September 2005. P

de Vaufleury, A., Kramarz, P., Binet, P., Caul, S., Andersen, M.N., Cortet, J., Plumey, E., Coeurdassier, M. & Krogh, P.H. 2006. Exposure and effects assessments of *Bt* maize on non-target organisms (gastropod, mycorrhizal fungi) in a semi-field microcosm experiment. *10th International Conference on Agricultural Biotechnology: Facts, Analysis and Policies,* Ravello, Italy, 29 June–2 July 2006. P

Dennis, P., Evans, D.E., Skartveit, J., Beaton, K., Elston, D.A., Pakeman, R., Redpath, S.M. 2006. Multitrophic consequences of changes to grazing regimes in the British uplands. *British Ecological Society Annual Meeting,* Oxford, 5–7 September 2006. P

Dick, M.A., Dobbie, K., Cooke, D.E.L. & Brasier, C.M. 2006. *Phytophthora captiosa* sp. nov. and *Phytophthora fallax* sp. nov. causing crown dieback of *Eucalyptus* in New Zealand. *Mycological Research* **110**, 393–404. J

Drew, J.E., Padidar, S., Horgan, G.W., Duthie, G.G., Russell, W., Reid, M., Duncan, G. & Rucklidge, G. 2006. Salicylate modulates oxidative stress in the rat colon: A proteomic approach. *Biochemical Pharmacology* **72**, 204–216. J

Druka, A., Muehlbauer, G., Druka, I., Caldo, R., Baumann, U., Rostoks, N., Schreiber, A., Wise, R., Close, T., Kleinhofs, A., Graner, A., Schulman, A.H., Langridge, P., Sato, K., Hayes, P., McNicol, J.W., Marshall, D.F. & Waugh, R. 2006. An atlas of gene expression from seed to seed through barley development. *Functional & Integrative Genomics* **6**, 202–211. J

Dunbabin, V.M. & Bengough, A.G. 2004. Incorporating rhizosphere processes into models of root system architecture. *Rhizosphere,* Munich, Germany, 12–17 September 2004. P

Dunbabin, V.M., McDermott, S. & Bengough, A.G. 2006. Upscaling from rhizosphere to whole root system: modelling the effects of phospholipid surfactants on water and nutrient uptake. *Plant and Soil* **283**, 57–72. J

Duncan, A.J., Ginane, C., Elston, D.A., Kunaver, A. & Gordon, I.J. 2006. How do herbivores trade-off the positive and negative consequences of diet selection decisions? *Animal Behaviour* **71**, 93–99. J

Duncan, S.H., Johnstone, A.M., Lobley, G.E., Holtrop, G., Belenguer, A., Bremner, D.M., Hrdinova, M. & Flint, H. J. 2006. Impact of reducing dietary carbohydrate intake upon the faecal microbial community and metabolites in human volunteers. *Reproduction Nutrition Development* **46 (Suppl. 1)**, S40. P

Evans, D.M., Redpath, S.M., Evans, S.A., Elston, D.A. & Dennis, P. 2005. Livestock grazing affects the egg size of an insectivorous passerine. *Biology Letters* **1**, 322–325. J

Evans, D.M., Redpath, S.M, Elston, D.A., Evans, S.A., Mitchell, R.J. & Dennis, P. 2006. To graze or not to graze? Sheep, voles, forestry and nature conservation in the British uplands. *Journal of Applied Ecology* **43**, 499–505. J

Firbank, L.G., Rothery, P., May, M.J., Clark, S.J., Scott, R.J., Stuart R.C., Boffey, C.W.H., Brooks, D.R., Champion, G.T., Haughton, A.J., Hawes, C., Heard, M.S., Dewar, A.M., Perry, J.N. & Squire, G.R. 2006. Effects of genetically modified herbicide-tolerant cropping systems on weed seedbanks in two years of following crops. *Biology Letters* **2**, 140–143. J

Fontaine, M.C., Baird, G., Connor, K.M., Rudge, K., Sales, J. & Donachie, W. 2006. Vaccination confers significant protection of sheep against infection with a virulent United Kingdom strain of *Corynebacterium pseudotuberculosis*. *Vaccine* **24**, 5986–5996. J

Ford, K.E., Gregory, P.J., Gooding, M.J. & Pepler, S. 2006. Genotype and fungicide effects on late-season root growth of winter wheat. *Plant and Soil* **284,** 33-44. J

George, T.S., Turner, B.L., Gregory, P.J., Cade-Menun, B.J. & Richardson, A.E. 2006. Depletion of organic phosphorus from Oxisols in relation to phosphatase activities in the rhizosphere. *European Journal of Soil Science* **57,** 47-57. J

Gheysen, G. & Jones, J.T. 2006. Molecular aspects of plant–nematode interactions. In: Perry, R.N. & Moens, M. (eds). *Plant Nematology.* CABI Publishing, Wallingford, Oxon, 234–254. R

Gibson, G.J., Otten, W., Filipe, J.A.N., Cook, A., Marion, G. & Gilligan, C.A. 2006. Bayesian estimation for percolation models of disease spread in plant populations. *Statistics and Computing* **16(4)**, 391–402. J

Gilroy, E.M., Venter, E., McLellan, H., Hein, I., Hrubikova, K., Holeva, M.C., Boevink, P.C., Loake, G.J., Lacomme, C.L. & Birch, P.R.J. 2006. Inducible disease resistance involves an apoplastic cysteine protease Cathepsin B. *Breeding for Inducible Resistance against Pests and Diseases. Proceedings of IOBC/WPRS Joint Working Group Meeting,* Heraklio, Crete, 27–29 April 2006, 20. P

Gimona, A. & Brewer, M.J. 2006. Local environmental effects and spatial effects in macroecological studies using mapped abundance classes: the case of the rook *Corvus frugilegus* in Scotland. *Journal of Animal Ecology* **75**, 1140–1146. J

Glasbey, C.A. 2005. How to segment 3-D images and analyse 1-D electrophoresis gels. *RSS Medical Section meeting*, London, 26 April 2005. P

Glasbey, C.A. 2005. Image warping and segmentation using generalisations of dynamic programming. *25th European Meeting of Statisticians*, Oslo, Norway, 24–29 July 2005. P

Glasbey, C.A. 2005. Image warping and segmentation using generalisations of dynamic programming. *AMSI Symposium on Recent Advances in Biostatistics, Bioinformatics and MCMC*, Sydney, Australia, 7–8 July 2005. P

Glasbey, C.A. 2005. Image warping and segmentation using generalisations of dynamic programming. *Statistical Society of Australia: Queensland Branch*, Brisbane, Australia, 5 July 2005. P

Glasbey, C.A. 2005. Problems at the interface between statistics, biomathematics and bioinformatics. *Workshop on The Mathematics of Complex Systems*, Bath Institute for Complex Systems, University of Bath, Bath, 31 January 2005. P

Glasbey, C.A. 2005. Seeing is believing? *Norwegian Statistical Society*, Oslo, Norway. 2005. P

Glasbey, C.A. & Allcroft, D.J. 2005. A STARMA model for solar radiation in a microclimate. *Workshop on Recent Advances in Modelling Spatio-temporal Data*, Southampton. 25–26 May 2005. P

Glasbey, C.A. & Khondoker, M.R. 2005. Correction for pixel censoring in cDNA microarrays. In: Francis, A.R., Matawie, K.M., Oshlack, A. & Smyth, G.K. (eds). *Statistical Solutions to Modern Problems: Proceedings of the 20th IWSM.* University of Western Australia, Sydney, Australia, 17–31. R

Glasbey, C.A. & Khondoker, M.R. 2005. Statistical models to correct for saturation effects in cDNA microarrays. *Biometrics Multi-Region Conference*, Leicester, 5–8 April 2005. P

Gordon, S.C., Birch, A.N.E. & Mitchell, C. 2006. Integrated pest management of pests of raspberry (*Rubus idaeus)* – Possible developments in Europe by 2015. *IOBC/WPRS Working Group. Integrated Plant Protection in Fruit Crops – Sub-Group Soft Fruits,* Stavanger, Norway, 5–8 October 2005. P

Gordon, S.C., Birch, A.N.E., Brennan, R., Graham, J., Barker, H., Dolan, A. & Jennings, S.N. 2006. Predicted developments in cane and bush fruit pest and disease management in Europe, with special reference to high health planting stock, genomics and plant breeding. *Cost 863 Euroberry,* Zagreb, Croatia, 19–22 April 2006. 6. P

Graham, J., Smith, K., Tierney, I., MacKenzie, K. & Hackett, C. 2005. Mapping gene *H* controlling cane pubescence in raspberry and its association with resistance to cane botrytis and spur blight, rust and cane spot. *Theoretical and Applied Genetics* **112**, 818-831. J

Gregory, A.S., Whalley, W.R., Watts, C.W., Bird, N.R.A., Hallett, P.D. & Whitmore, A.P. 2006. Calculation of the compression index and precompression stress from soil compression test data. *Soil and Tillage Research* **89**, 45–57. J

Gregory, P.J. 2006. Agriculture futures: can production and ecosystem services be delivered? The Inaugural Hugh Bunting Memorial Lecture. *Tropical Agriculture Association, Newsletter* **26,** 5-9. P

Gregory, P.J. 2006. Environmental change and sustainability: Challenges for crop protection. *Proceedings of Crop Protection in Northern Britain,* Dundee, 28 February–1 March 2006, 1–2. P

Gregory, P.J. 2006. Plant Roots: *Growth, Activity and Interaction with Soils.* Blackwell Publishing, Oxford, UK, 318 p. R

Gregory, P.J. 2006. Roots, rhizosphere and soil: the route to a better understanding of soil science? *European Journal of Soil Science* **57,** 2-12. J

Gregory, P.J. 2006. The evolving science base of IGER North Wyke. *IGER Innovations,* **10,** 62-63. O

Griffiths, B.S., Caul, S., Thompson, J., Birch, A.N.E., Cortet, J., Andersen, M.N. & Krogh, P.H. 2006. Microbes and microfauna in cropping systems with genetically modified plants. *10th International Conference on Agricultural Biotechnology: Facts, Analysis and Policies,* Ravello, Italy, 29 June–2 July 2006. P

Griffiths, B.S., Caul, S., Thompson, J., Birch, A.N.E., Scrimgeour, C.M., Cortet, J., Foggo, A., Hackett, C.A. & Krogh, P.H. 2006. Soil microbial and faunal community responses to *Bt* maize and insecticide in two soils. *Journal of Environmental Quality* **35**, 734–741. J

Griffiths, B.S., Donn, S., Neilson, R. & Daniell, T.J. 2006. Molecular sequencing and morphological analysis of a nematode community. *Applied Soil Ecology* **32**, 325–337. J

Grzegorczyk, M., Werhli, A.V., Urfer, W. & Husmeier, D. 2006. Reverse engineering protein regulatory networks using graphical models. *German Conference on Bioinformatics*, Tübingen, Germany, 20–22 September 2006. P

Hamza, O., Bengough, A.G., Bransby, M.F., Davies, M.C.R. & Hallett, P.D. 2006. Biomechanics of plant roots: estimating localised deformation with particle image velocimetry. *Biosystems Engineering* **94**, 119–132. J

Hancock, R.D. 2006. Boosting vitamin C content in blackcurrants. *BBSRC Business* **July 2006**, 12–13. O

Hancock, R.D. 2006. Improving the nutritional value of crops by genetic modification: Problems and opportunities illustrated by vitamin C. *Asia Pacific Biotech News* **10,** 237–239. O

Hancock, R.D. 2006. Thermal treatments for enhancing shelf life of minimally processed foods. *Excellence in Food Manufacture 2006,* London, 1 November 2006. P

Hancock, R.D., Walker, P.G., Pont, S.D.A., Smirnoff, N. & Viola, R. 2006. Ascorbic acid conjugates in phloem exudates of *Cucurbitaceae*. *Proceedings of the 15th Congress of the Federation of European Societies of Plant Biology,* Lyon, France, 17–21 July 2006. P

Haupt, S., Roberts, A.G., Cowan, G.H., Faulkner, C., Torrance, L. & Oparka, K. 2006. There and back again – PD targeting meets vesicle recycling. *Plasmodesmata 2006,* Pitlochry, Scotland, 30 July–3 August 2006. P

Hawes, C. & Reed, C.A. 2006. Theoretical steps towards modelling resilience in complex systems. *Computational Science and its Applications – ICCSA 2006,* Glasgow, Scotland, 8–11 May 2006. Springer, Berlin, 644–653. P

Heckmann, L-H., Griffiths, B.S., Caul, S., Thompson, J., Pusztai-Carey, M., Moar, W.J., Andersen, M.N. & Krogh, P.H. 2006. Consequences for *Protaphorura armata* (Collembola: Onychiuridae) following exposure to genetically modified *Bacillus thuringiensis* (*Bt*) maize and non-*Bt* maize. *Environmental Pollution* **142**, 212–216. J

Hilbeck, A., Andow, D.A., Arpaia, S., Birch, A.N.E., Fontes, E.M.G., Lövei, G., Sujii, E., Wheatley, R.E. & Underwood, E. 2006. Methodology to support non-target and biodiversity risk assessment. In: Hilbeck, A., Andow, D.A. & Fontes, E.M.G. (eds). *Environmental Risk Assessment of Genetically Modified Organisms Volume 2: Methodologies for assessing Bt cotton in Brazil.* CABI Publishing, Wallingford, UK, 108–132. R

Hilbeck, A., Andow, D.A., Birch, A.N.E., Fitt, G.P., Johnston, J., Nelson, K.C., Osir, E., Songa, J., Underwood, E. & Wheatley, R.E. 2004. Risk assessment of *Bt* maize in Kenya: Synthesis and recommendations. In: Hilbeck, A. & Andow, D. (eds). *Environmental Risk Assessment of Genetically Modified Organisms Volume 1: A case study of Bt maize in Kenya.* CABI International, Wallingford, UK, 251–270. R

Hilton, A.J., Lees, A.K., Brierley, J.L. & Wale, S.J. 2006. Towards developing a risk management scheme for soil-borne diseases of potato. *Proceedings of Crop Protection in Northern Britain,* Dundee, 28 February–1 March 2006, 359–364. P

Hoggard, N., Johnstone, A.M., Faber, P., Gibney, E. R., Elia, M., Lobley, G.E., Rayner, V., Horgan, G.W., Hunter, L., Bashir, S. & Stubbs, R.J. 2004. Plasma concentrations of □-MSH, AgRP and leptin in lean and obese men and their relationship to differing states of energy balance perturbation. *Clinical Endocrinology* **61**, 31–39. J

Holeva, R., Phillips, M.S., Neilson, R., Brown, D.J.F., Young, V., Boutsika, K. & Blok, V.C. 2006. Real-Time PCR detection and quantification of vector trichodorid nematodes and *Tobacco rattle virus*. *Molecular and Cellular Probes* **20**, 203–211. J

Holtrop, G. & Horgan, G.W. 2005. Risk assessment of current shellfish toxin monitoring schemes and development of improved schemes. *Final Report for Food Standards Agency* **Project S01026.** T

Holtrop, G., Petrie, J., McElhiney, J. & Dennison, N. 2006. Can general anaesthesia be used for the Paralytic Shellfish Poison bioassay? *Toxicon* **47**, 336–347. J

Horgan, G.W., Travis, A.J. & Liang, J. 2005. Automatic recognition of maize cell types using context information. *Micron* **36**, 163–167. J

Hudson, I., Keatley, M. & Roberts, A.M.I. 2005. Statistical methods in phenological research. In: Francis, A.R., Matawie, K.M., Oshlack, A. & Smyth, G.K. (eds). *Statistical Solutions to Modern Problems: Proceedings of the 20th IWSM.* University of Western Australia, Sydney, Australia, 259–270. R

Husmeier, D. 2005. A leisurely look at statistical inference. In: Husmeier, D., Dybowski, R. & Roberts, S. (eds) *Probabilistic Modeling in Bioinformatics and Medical Informatics*, Springer Verlag, Berlin, 3–16. R

Husmeier, D. 2005. Detecting mosaic structures in DNA sequence alignments. *Workshop on Statistics in Genomics and Proteomics (WSGP)*, Estoril, Portugal, 5–8 October 2005. P

Husmeier, D. 2005. Discriminating between rate heterogeneity and interspecific recombination in DNA sequence alignments with phylogenetic factorial hidden Markov models. *Bioinformatics* **21**, ii166–ii172. P

Husmeier, D. 2005. Inferring genetic regulatory networks from microarray experiments with Bayesian networks. In: Husmeier, D., Dybowski, R. & Roberts, S. (eds). *Probabilistic Modeling in Bioinformatics and Medical Informatics*, Springer Verlag, Berlin, 239–268. R

Husmeier, D. 2005. Introduction to learning Bayesian networks from data. In: Husmeier, D., Dybowski, R. & Roberts, S. (eds). *Probabilistic Modeling in Bioinformatics and Medical Informatics*, Springer Verlag, Berlin, 17–58. R

Husmeier, D. 2005. Introduction to statistical phylogenetics. In: Husmeier, D., Dybowski, R. & Roberts, S. (eds). *Probabilistic Modeling in Bioinformatics and Medical Informatics*, Springer Verlag, Berlin, 83–146. R

Husmeier, D. 2005. Learning local gene interaction networks from noisy gene expression data with probabilistic graphical models. *Computational Methods in Systems Biology (CMSB)*, Edinburgh, 2–10 April 2005. P

Husmeier, D. 2005. Phylogenetic factorial hidden Markov models for detecting mosaic structures in DNA sequence alignments. *13th Annual International Conference on Intelligent Systems for Molecular Biology*, Detroit, 25–29 June 2005. P

Husmeier, D. 2005. Predicting mosaic structures in DNA sequence alignments. *Royal Statistical Society Bioinformatics Seminar*, Newcastle, 25 February 2005. P

Husmeier, D. 2005. Probabilistic methods for post-genomic data integration. *Systems Biology Club*, Edinburgh, 26 May 2005. P

Husmeier, D. 2005. Reverse engineering of gene regulatory networks. *Systems Biology Club*, Edinburgh, 12 May 2005. P

Husmeier, D. & Wright, F. 2005. Detecting recombination in DNA sequence alignments. In: Husmeier, D., Dybowski, R. & Roberts, S. (eds). *Probabilistic Modeling in Bioinformatics and Medical Informatics*, Springer Verlag, Berlin, 147–188. R

Husmeier, D., Dybowski, R. & Roberts, S. (eds). 2005. *Probabilistic Modeling in Bioinformatics and Medical Informatics*, Springer Verlag, Berlin, 508p. R

Iannetta, P.P.M., Laarhoven, L.-J., Medina-Escobar, N., James, E.K., McManus, M.T., Davies, H.V. & Harren, F.J.M. 2006. Ethylene and carbon dioxide production by developing strawberries show a correlative pattern that is indicative of ripening climacteric fruit. *Physiologia Plantarum* **127**, 247–259. J

Iason, G.R., Lennon, J.J., Pakeman, R.J., Thoss, V., Beaton, J.K., Sim, D.A. & Elston, D.A. 2005. Does chemical composition of individual Scots pine trees determine the biodiversity of their associated ground vegetation? *Ecology Letters* **8**, 364–369. J

Jiang, R.H.Y., Tyler, B.M., Whisson, S.C., Hardham, A.R. & Govers, F. 2006. Ancient origin of elicitin gene clusters in *Phytophthora* genomes. *Molecular Biology and Evolution* **23**, 338–351. J

Johnson, S.N. 2006. Are ecologists becoming more gregarious? *Bulletin of the British Ecological Society* **37 (1),** 23. O

Johnson, S.N. 2006. Grazing in the dark: how a root-feeding insect finds its host plant. *VIIIth European Congress of Entomology,* Izmir, Turkey, 17–22 September 2006. P

Johnson, S.N. & Gregory, P.J. 2006. Chemically mediated host–plant location and selection by root-feeding insects. *Physiological Entomology* **31**, 1–13. J

Johnson, S.N., Birch, A.N.E., Gregory, P.J. & Murray, P.J. 2006. The 'mother knows best' principle: should soil insects be included in the preference–performance debate? *Ecological Entomology* **31**, 395–401. J

Johnson, S.N., Hallett, P.D., Gillespie, T.L. & Halpin, C. 2006. Wireworms on the wacky-backy: how the biomechanics of lignin modified tobacco roots influence root herbivory. *Annual Meeting of the British Ecological Society,* University of Oxford, 5–7 September 2006. P

Johnson, S.N., Zhang, X.X., Crawford, J.W., Gregory, P.J., Hix, N.J., Jarvis, S.C., Murray, P.J. & Young, I.M. 2006. Effects of CO_2 on the searching behaviour of the root-feeding clover weevil *Sitona lepidus* (Coleoptera: Curculionidae). *Bulletin of Entomological Research* **96**, 361–366. J

Jones, A.T., Cowan, G.H., McGavin, W.J., Roberts, I.M. & Torrance, L. 2005. Production and properties of monoclonal antibodies to *Solanum nodiflorum mottle sobemovirus*. *Annals of Applied Biology* **146**, 321–325. J

Jones, A.T., Kumar, P.L., Saxena, K.B., Kulkarni, N.K., Muniyappa, V. & Waliyar, F. 2004. Sterility mosaic disease – the 'Green Plague' of Pigeonpea: advances in understanding the etiology, transmission and control of a major virus disease. *Plant Disease* **88**, 436–445. J

Jones, J.T., Furlanetto, C. & Kikuchi, T. 2006. Horizontal gene transfer from bacteria and fungi as a driving force in the evolution of plant parasitism in nematodes. *Nematology* **7**, 641–646. J

Jopson, N.B. & Glasbey, C.A. 2005. Development of technologies and software for body composition and carcass quality. *The International Skjervold Symposium 2005: Lamb Innovation*, Hamar, Norway, 2–3 June 2005. P

Judge, J., Kyriazakis, I., Greig, A., Allcroft, D.J. & Hutchings, M.R. 2005. Clustering of *Mycobacterium avium* subsp. *paratuberculosis* in rabbits and the environment: How hot is a hot spot? *Applied and Environmental Microbiology* **71**, 6033–6038. J

Karley, A.J. & Marshall, B. 2006. Functional-structural modelling in crop production as a tool to assess the impact of competition for light and nutrients on arable communities. In: Vos, J., Marcelis, L.F.M., de Visser, P.H.B., Struik, P.C. & Evers, J.B. (eds). *Functional-Structural Plant Modelling in Crop Production. Proceedings of the Frontis Workshop, Wageningen, The Netherlands, 5-8 March 2006.* Springer, Amsterdam, 231–241. P

Karley, A.J., Valentine, T.A., Greig, J., Iannetta, P.P.M. & Squire, G.R. 2006. How does root morphology and response to nutrients relate to life history traits in ecotypes of *Capsella bursa-pastoris? 14th New Phytologist Symposium,* The Royal Society, London, 23–24 January 2006. P

Kasprowicz, L., Barker, H., Malloch, G., Foster, S., Anstead, J., Pickup, J., King, L., Evans, A. & Fenton, B. 2006. Tracking MACE resistant clones of the peach-potato aphid *Myzus persicae* (Sulzer) (Hemiptera: Aphididae), in Scotland. *Proceedings of Crop Protection in Northern Britain,* Dundee, 28 February–1 March 2006, 261–266. P

Kevekordes, K., Holland, D., Häubner, N., Jenkins, S., Koss, R., Roberts, S., Raven, J.A., Scrimgeour, C.M., Shelly, K., Stojkovic, S. & Beardall, J. 2006. Inorganic carbon acquisition by eight species of *Caulerpa* (Caulerpaceae, Chlorophyta). *Phycologia* **45**, 442–449. J

Khondoker, M.R., Glasbey, C.A. & Worton, B.J. 2006. Statistical estimation of gene expression using multiple laser scans of microarrays. *Bioinformatics* **22**, 215–219. J

Kikuchi, T., Shibuya, H., Aikawa, T. & Jones, J.T. 2006. Cloning and characterization of pectate lyases expressed in the esophageal gland of the pine wood nematode *Bursaphelenchus xylophilus*. *Molecular Plant–Microbe Interactions* **19**, 280–287. J

Kim, S.H., Ryabov, E.V., MacFarlane, S., Kalinina, N.O., Rakitina, D.V., Haupt, S., Gillespie, T., Brown, J.W.S. & Taliansky, M.E. 2006. Involvement of the nucleolus in *Umbravirus* long-distance movement. *Plasmodesmata 2006,* Pitlochry, Scotland, 30 July–3 August 2006. P

Krogh, P.H., Demšar, D., Cortet, J., Neumann-Andersen, M., Debeljak, M., Griffiths, B.S., Caul, S., Dzeroski, S., Žnidaršic, M. & Bohanec, M. 2006. Decision support systems for soil quality assessment of farming systems. *Society of Environmental Toxicology and Chemistry (SETAC) Europe 16th Annual Meeting,* The Hague, Netherlands, 7–11 May 2006. P

Krogh, P.H., Griffiths, B.S., Caul, S., Neumann-Andersen, M., Sausse, C., Demšar, D., Debeljak, M., Holmstrup, M., Heckmann, L.H. & Cortet, J. 2006. Effects of Basta tolerant and *Bt* corn with normal tillage and reduced tillage

on earthworms in a field experiment. *10th International Conference on Agricultural Biotechnology: Facts, Analysis and Policies,* Ravello, Italy, 29 June–2 July 2006. P

Krogh, P.H., Neumann-Andersen, M., Griffiths, B.S., Holmstrup, M., Vercesi, M.L., Scott-Fordsmand, J., Caul, S., Debeljak, M., Sausse, C., Heckmann, L. & Cortet, J. 2006. Influence of a monoculture *Bt* maize cropping system on earthworm communities at three European locations. *Society of Environmental Toxicology and Chemistry (SETAC) Europe 16th Annual Meeting,* The Hague, Netherlands, 7–11 May 2006. P

Kuan, H.L., Fenwick, C., Glover, L.A., Griffiths, B.S. & Ritz, K. 2006. Functional resilience of microbial communities from perturbed upland grassland soils to further persistent or transient stresses. *Soil Biology & Biochemistry* **38**, 2300–2306. J

Kühn, I., Bierman, S.M., Durka, W. & Klotz, S. 2006. Relating geographical variation in pollination types to environmental and spatial factors using novel statistical methods. *New Phytologist* **172**, 127–139. J

Kusnarta, Mahrup, Ma'shum, M., Sukartono, Tisdall, J.M., Gill, J.S. & McKenzie, B.M. 2006. Do soil strength and soil water profile change under different soil management on semi-arid rainfed Vertisols of Southern Lombok, Eastern Indonesia? *ASSSI-ASPAC National Soils Conference,* Adelaide, Australia, 3–7 December 2006. P

Lacomme, C., Faivre-Rampant, O., Gilroy, E., Valentine, T.A., Shaw, J., Hrubikova, K., Blok, V.C., Hein, I., Haupt, S., Loake, G., Birch, P.R.J., Taylor, M.A. & Oparka, K. 2004. Virus-induced gene silencing vector development for functional studies in Solanaceae. *1st Solanaceae Genome Workshop,* Wageningen, The Netherlands, 19–21 September 2004. P

Lapierre, H., Pacheco, D., Berthiaume, R., Ouellet, D.R., Schwab, C.G., Dubreuil, P., Holtrop, G. & Lobley, G.E. 2006. What is the true supply of amino acids for a dairy cow? *Journal of Dairy Science* **89(E. Suppl.)**, E1–E14. P

Latijnhouwers, M., Hawes, C. & Carvalho, C. 2005. Holding it all together? Candidate proteins for the plant Golgi matrix. *Current Opinion in Plant Biology* **8**, 632–639. J

Lazarova, S.S., Brown, D.J.F., Malloch, G., Oliveira, C.M.G., Fenton B. & Neilson, R. 2006. Sequence analysis of ribosomal and mitochondrial DNA of *Xiphinema americanum*-group populations. *European Society of Nematologists Biennial Meeting,* Blagoevgrad, Bulgaria, 5–9 June 2006. P

Lees, A.K., Cooke, D.E.L., Colon, L.T., Grønbech-Hansen, J., Lassen, P., Andrivon, D., Hermansen, A. & Zimnoch-Guzowska, E. 2006. Eucablight – a late blight network for Europe. *Proceedings of Crop Protection in Northern Britain,* Dundee, 28 February–1 March 2006, 335–340. P

Lees, A.K., Wale, S.J., van de Graaf, P. & Brierley, J.L. 2005. The use of molecular diagnostics to investigate the epidemiology of potato diseases. *Australasian Plant Pathology* **34**, 449–455. J

Lees, A.K., Wattier, R., Shaw, D.S., Sullivan, L., Williams, N.A. & Cooke, D.E.L. 2006. Novel microsatellite markers for the analysis of *Phytophthora infestans* populations. *Plant Pathology* **55**, 311–319. J

Lehesranta, S.J., Davies, H.V., Shepherd, L.V.T., Koistinen, K.M., Massat, N., Nunan, N., McNicol, J.W. & Kärenlampi, S.O. 2006. Proteomic analysis of the potato tuber life cycle. *Proteomics* **6**, 6042–6052. J

Lehrach, W.P., Husmeier, D. & Williams, C.K.I. 2005. A regularised discriminative model for the prediction of protein–peptide interactions. *European Conference on Computational Biology*, Madrid, Spain, 28 September–1 October 2005. P

Lehrach, W.P., Husmeier, D. & Williams, C.K.I. 2006. A regularized discriminative model for the prediction of protein–peptide interactions. *Bioinformatics* **22**, 532–540. J

Lewis, S., Benvenuti, S., Daunt, F., Wanless, S., Dall'Antonia, L., Luschi, P., Elston, D.A., Hamer, K.C. & Sherratt, T.N. 2004. Partitioning of diving effort in foraging trips of northern gannets. *Canadian Journal of Zoology* **82**, 1910–1916. J

Liu, H., Humphris, S.N., Hedley, P.E., Pritchard, L., Hyman, L., Morris, J., Birch, P.R.J. & Toth, I.K. 2006. The identification of novel *Erwinia* genes involved in disease. *Proceedings of Crop Protection in Northern Britain,* Dundee, 28 February–1 March 2006, 331–334. P

Liu, J. 2006. Dissipation and maintenance of stable states in an enzymatic system: analysis and simulation. *Biophysical Chemistry* **120**, 207–214. J

Liu, J. 2006. Kinetic constraints for formation of steady states in biochemical networks. *International Specialised Symposium on Yeasts ISSY25 Systems Biology of Yeasts – From Models to Applications,* Hanasaari Espoo, Finland, 18–21 June 2006. P

Lobley, G.E., Wester, T.J., Holtrop, G., Dibner, J.J. Parker, D.S. & Vázquez-Añón, M. 2006. Absorption and digestive tract metabolism of 2-hydroxy-4-methylthiobutanoic acid in lambs. *Journal of Dairy Science* **89**, 3508–3521. J

Logue, D.N., Offer, J.E. & Brocklehurst, S. 2006. Animal health impacts of early lactation management: The effect on lameness. *UK Vet Livestock* **11 (3)**. O

Long, D.G., Paton, J.A., Squirrell, J., Woodhead, M. & Hollingsworth, P.M. 2006. Morphological, ecological and genetic evidence for distinguishing *Anastrophyllum joergensenii* Schiffn. and *A. alpinum* Steph. (Jungermanniopsida: Lophoziaceae). *Journal of Bryology* **28**, 108–117. J

Low, A.S., Dziva, F., Torres, A.G., Martinez, J.L., Rosser, T., Naylor, S., Spears, K., Holden, N., Mahajan, A., Findlay, J., Sales, J., Smith, D.G.E., Low, J.C., Stevens, M.P. & Gally, D.L. 2006. Cloning, expression, and characterization of a fimbrial operon, F9, from enterohemorrhagic *Escherichia coli* O157:H7. *Infection and Immunity* **74**, 2233–2244. J

McCue, K.F., Allen, P.A., Shepherd, L.V.T., Blake, A., Novy, R., Stewart, D., Davies, H.V. & Belknap, W.R. 2006. Manipulation and compensation of steroidal glycoalkaloid biosynthesis in potatoes. *International Solanaceae Conference and Solanaceae Genomics Network,* Madison, Wisconsin, 23–27 July 2006. P

McDougall, G.J. & Stewart, D. 2006. Berry polyphenols: Bioactivities, bioavailability and health effects. *IFHIC 2006 International Conference,* Malmo, Sweden, 25–27 October 2006. P

McDougall, G.J. & Stewart, D. 2006. Scottish berries – potential for dietary chemoprevention? *Scottish Society for Experimental Medicine,* Edinburgh, 10 November 2006. P

McLean, K., McNicoll, J., Bradshaw, J.B., Hein, I., Milbourne, D. & Bryan, G. 2006. Strategies for fine mapping and isolation of resistance QTLs on Linkage Groups IV and V of potato. *International Solanaceae Conference and Solanaceae Genomics Network,* Madison, Wisconsin, 23–27 July 2006. P

McVittie, A., Moran, D. & Nevison, I.M. 2006. Public preferences for broiler chicken welfare: Evidence from stated preference studies. *Agricultural Economics Society 80th Annual Conference*, Paris, France, 30–31 March 2006. P

Malloch, G., King, L., Borthwick, F., Kasprowicz, L., Pickup, J. & Fenton, B. 2006. A genotypic analysis of peach-potato aphids caught in Scottish suction traps. *Proceedings of Crop Protection in Northern Britain,* Dundee, 28 February-1 March 2006, 319–324. P

Manachini, B., Anyango, B., Ngog, B.H., Zwahlen, C., Toan, P.V., Wheatley, R.E., Hilbeck, A. & Andow, D. 2006. Impact of transgenic plants on soil ecosystem functioning: The Vietnam case. *10th International Conference on Agricultural Biotechnology: Facts, Analysis and Policies,* Ravello, Italy, 29 June–2 July 2006. P

Mao, X., Hu, F., Griffiths, B.S. & Li, H. 2006. Bacterial-feeding nematodes enhance root growth of tomato seedlings. *Soil Biology and Biochemistry* **38**, 1615–1622. J

Martens, H., Roberts, A.G., Oparka, K. & Schulz, A. 2006. Endomembrane coupling between sieve element and companion cell. *Plasmodesmata 2006,* Pitlochry, Scotland, 30 July–3 August 2006. P

Mayer, C-D. & Glasbey, C.A. 2005. Statistical methods in microarray gene expression data analysis. In: Husmeier, D., Dybowski, R. & Roberts, S. (eds). *Probabilistic Modeling in Bioinformatics and Medical Informatics*, Springer Verlag, Berlin, 211–238. R

Mayo, M.A. & Brown, D.J.F. 2004. Nematode transmission. In: Lapierre, H. & Signoret, P. (eds). *Viruses and Virus Diseases of the Poaceae (Gramineae).* INRA Editions, Paris. R

Mazlan, N., Horgan, G.W. & Stubbs, R.J. 2006. Energy density and weight of food affect short-term caloric compensation in men. *Physiology and Behavior* **87**, 679–686. J

Meharg, A.A., Deacon, C., Edwards, K.J., Donaldson, M., Davidson, D.A., Spring, C., Scrimgeour, C.M., Feldmann, J. & Rabb, A. 2006. Ancient manuring practices pollute arable soils at the St Kilda World Heritage Site, Scottish North Atlantic. *Chemosphere* **64**, 1818–1828. J

Meharg, A.A., Scrimgeour, C.M., Hossain, S.A., Fuller, K., Cruickshank, K., Williams, P.N. & Kinniburgh, D.G. 2006. Codeposition of organic carbon and arsenic in Bengal Delta aquifers. *Environmental Science & Technology* **40**, 4928–4935. J

Mendonça-Hagler, L.C., de Melo, I.S., Valadares-Inglis, M.C., Anyango, B.M., Siqueira, J.O., Toan, Pham Van & Wheatley, R.E. 2006. Non-target and biodiversity impacts in soil. In: Hilbeck, A., Andow, D. & Fontes, E.M.G. (eds). *Environmental Risk Assessment of Genetically Modified Organisms Volume 2: Methodologies for assessing Bt cotton in Brazil.* CABI Publishing, Wallingford, UK, 225–260. R

Milbourne, D., Isidore, E., van Os, H., Andrzejewski, S., Bakker, J., Buntjer, J., Caromel, B., van Eck, H., Ghareeb, B., Lefebvre, V., Ritter, E., van der Voort, J.R., Rousselle-Bourgeois, F., Linton, S., McNicoll, J., McLean, K., Bryan, G.J. & Waugh, R. 2001. An ultra-high density genetic linkage map of potato as a platform for physical/gene content mapping and map based cloning. *Proceedings of the XVI Eucarpia Congress,* Edinburgh, 10–14 September 2001. P

Miller, T., Stewart, D. & Blok, V.C. 2006. Metabolic profiling of the response in susceptible and resistant Solanaceae to plant parasitic nematodes. *International Solanaceae Conference and Solanaceae Genomics Network*, Madison, Wisconsin, 23–27 July 2006. P

Moleleki, L.N., Birch, P.R.J. & Toth, I.K. 2006. *Erwinia* overcomes potato resistance by attacking its defences. *Proceedings of Crop Protection in Northern Britain,* Dundee, 28 February–1 March 2006, 325–330. P

Moloney, C., Griffin, D., Bradshaw, J., Bryan, G. & Milbourne, D. 2006. Developing MAS for the major heritable component of the H3-based resistance to *Globodera pallida* pathotype Pa2/3 in potato. *International Solanaceae Conference and Solanaceae Genomics Network*, Madison, Wisconsin, 23–27 July 2006. P

Morris, W.L., Ducreux, L.J.M., Fraser, P.D., Millam, S. & Taylor, M.A. 2006. Engineering ketocarotenoid biosynthesis in potato tubers. *Metabolic Engineering* **8**, 253–263. J

Muehlbauer, G.J., Bhau, B.S., Syed, N.H., Heinen, S., Cho, S., Marshall, D.F., Pateyron, S., Buisine, N., Chalhoub, B. & Flavell, A.J. 2006. A *hAT* superfamily tranposase recruited by the cereal grass genome. *Molecular Genetics and Genomics* **275**, 553–563. J

Navajas, E., McLean, K.A., Glasbey, C.A., Lambe, N. R., Fisher, A.V., Bunger, L. & Simm, G. 2005. Assessing muscularity in lambs using spiral CT scanning. *The International Skjervold Symposium 2005: Lamb Innovation*, Hamar, Norway, 2–3 June 2005. P

Newton, A.C. 2006. Variety and species mixtures - Diseases and soil: Introduction. *COST 860 SUSVAR Workshop on Cereal Crop Diversity: Implications for Production and Products,* La Besse, France, 12–15 June 2006. P

Newton, A.C. & Thomas, W.T.B. 2006. Mapping resistance to spots and blotches in spring barley. *3rd International Barley Leaf Blight Workshop,* Edmonton, Canada, 23–27 July 2006. P

Newton, A.C. & Thomas, W.T.B. 2006. Resistance to spots and blotches in spring barley. *Proceedings of Crop Protection in Northern Britain,* Dundee, 28 February–1 March 2006, 191–194. P

Newton, A.C. & Swanston, J.S. 2006. Variety Mixtures. *SAC–SCRI Topic Sheet.* T

Newton, A.C., Begg, G.S. & Guy, D. 2006. Controlling leaf blights in practice with variety mixtures. *3rd International Barley Leaf Blight Workshop,* Edmonton, Canada, 23–27 July 2006. P

Newton, A.C., Begg, G.S. & Swanston, J.S. 2006. The effects of spatial scaling in host heterogeneity on epidemics of a plant pathogen. *COST 860 SUSVAR Workshop on Cereal Crop Diversity: Implications for Production and Products,* La Besse, France, 12–15 June 2006. P

Newton, A.C., Lowe, R., Hackett, C.A. & Wale, S.J. 2006. Measuring crop (biotic and abiotic) stress using reflectance – better than disease assessments? *Proceedings of Crop Protection in Northern Britain,* Dundee, 28 February–1 March 2006, 143–148. P

Newton, A.C., Lyon, G.D., Begg, G.S., Zhan, J., Guy, D. & Walters, D.R. 2006. Deployment strategies for crops with inducible resistance. *Breeding for Inducible Resistance against*

Pests and Diseases. Proceedings of IOBC/WRPS Joint Working Group Meeting, Heraklio, Crete, 27–29 April 2006, 20. P

Newton, A.C., McRoberts, N. & Hughes, G. 2006. Information technology in plant disease epidemiology. In: Cooke, B.M., Jones, D.G. & Kaye, B. (eds). *The Epidemiology of Plant Diseases. 2nd ed.* Kluwer Academic Publishers, Dordrecht, 335–356. R

Nicholson, C., McLaren, K., Scott, C., Sims, S., Beasley, H., Bishop, G., Seymour, G., Bryan, G., Humphray, S. & Rogers, J. 2006. Mapping, sequencing and finishing the gene space of *Solanum lycopersicum* chromosome 4. *International Solanaceae Conference and Solanaceae Genomics Network,* Madison, Wisconsin, 23–27 July 2006. P

Niehl, A., Lacomme, C., Erban, A., Kopka, J., Krämer, U. & Fisahn, J. 2006. Systemic *Potato virus X* infection induces defence gene expression and accumulation of β-phenylethylamine-alkaloids in potato. *Functional Plant Biology* **33**, 593–604. J

Nunan, N., Singh, B., Reid, E., Ord, B., Papert, A., Squires, J., Prosser, J.I., Wheatley, R.E., McNicol, J.W. & Millard, P. 2006. Sheep-urine-induced changes in soil microbial community structure. *FEMS Microbiology Ecology* **56**, 310–320. J

Nuopponen, M., Birch, G.M., Sykes, R.J., Lee, S.J. & Stewart, D. 2006. Estimation of wood density and chemical composition by means of Diffuse Reflectance Mid-Infrared Fourier Transform (DRIFT-MIR) spectroscopy. *Journal of Agricultural and Food Chemistry* **54**, 34–40. J

Nuopponen, M.H., Wikberg, H.I., Birch, G.M., Jääskeläinen, A.-S., Maunu, S.L., Vuorinen, T. & Stewart, D. 2006. Characterization of 25 tropical hardwoods with Fourier transform infrared, ultraviolet resonance Raman and ^{13}C-NMR cross-polarization/magic-angle spinning NMR spectroscopy. *Journal of Applied Polymer Science* **102**, 810–819. J

Nussey, D.H., Clutton-Brock, T.H., Elston, D.A., Albon, S. D. & Kruuk, L.E.B. 2005. Phenotypic plasticity in a maternal trait in red deer. *Journal of Animal Ecology* **74**, 387–396. J

O'Kennedy, N., Crosbie, L.C., Whelan, S., Luther, V., Horgan, G.W., Broom, J.I., Webb, DJ. & Dutta-Roy, A. 2006. Effects of tomato extract on platelet function: a double-blinded crossover study in healthy humans. *American Journal of Clinical Nutrition* **84**, 561–569. J

Oliva, R., Chacon, G., Cooke, D.E.L., Lees, A.K. & Forbes, G. 2006. Is *Phytophthora infestans* a good taxonomist – host recognition in the *Phytophthora/Solanum* interaction? *International Solanaceae Conference and Solanaceae Genomics Network,* Madison, Wisconsin, 23–27 July 2006. P

Öpik, M. 2006. Composition of root-colonizing AM fungal communities in ecosystems around the globe, with an insight to a boreal forest. *5th International Conference on Mycorrhiza,* Granada, Spain, 23–27 July 2006. P

Özbilgin, H., Ferro, R.S.T., Robertson, J.H.B., Holtrop, G. & Kynoch, R.J. 2006. The seasonal variation in trawl codend selection of northern North Sea haddock. *ICES Journal of Marine Science* **63**, 737–748. J

Offer, J.E., Mason, C., Jack, M., Logue, D.N. & Brocklehurst, S. 2006. The effect of genetic and management strategies on lameness in dairy cattle. *24th World Buiatrics Congress*, Nice, France, 15–19 October 2006. P

Pallini, A., Silvie, P., Monnerat, R., Ramalho, F., Songa, J.M. & Birch, A.N.E. 2006. Non-target and biodiversity impacts on parasitoids. In: Hilbeck, A., Andow, D. & Fontes, E.M.G. (eds). *Environmental Risk Assessment of Genetically Modified Organisms Volume 2: Methodologies for assessing Bt cotton in Brazil.* CABI Publishing, Wallingford, UK, 200–224. R

Palukaitis, P. 2004. Plant diseases caused by subviral agents. In: Goodman, R.M. (ed.). *Encyclopedia of Plant & Crop Science.* Dekker, New York, 956–959. R

Palukaitis, P. & MacFarlane, S.A. 2006. Viral counter-defense molecules. In: Loebenstein, G. & Carr, J.P. (eds). *Natural Resistance Mechanisms of Plants to Viruses.* Springer, Berlin, 165–186. R

Paulo, M.J., van der Voet, H., Wood, J.C., Marion, G.R. & van Klaveren, J.D. 2006. Analysis of multivariate extreme intakes of food chemicals. *Food and Chemical Toxicology* **44 (7)**, 994–1005. J

Pearce, M.C., Evans, J., McKendrick, I.J., Smith, A.W., Knight, H.I., Mellor, D.J., Woolhouse, M.E.J., Gunn, G. J. & Low, J.C. 2006. Prevalence and virulence factors of *Escherichia coli* serogroups O26, O103, O111 and O145 shed by cattle in Scotland. *Applied and Environmental Microbiology* **72**, 653–659. J

Pendle, A.F., Clark, G.P., Boon, R., Lewandowska, D., Lam, Y.W., Andersen, J., Mann, M., Lamond, A.I., Brown, J.W.S. & Shaw, P.J. 2005. Proteomic analysis of the *Arabidopsis* nucleolus suggests novel nucleolar functions. *Molecular Biology of the Cell* **16**, 260–269. J

Pérez-Barbería, F.J., Walker, D.M. & Gordon, I.J. 2004. Sex differences in feeding behaviour at feeding station scale in Soay sheep (*Ovis aries*). *Behaviour* **141**, 999–1020. J

Powell, W., Waugh, R., Bradshaw, J.E., Russell, J.R. & Ramsay, L. 2006. Introduction to classical genetics and plant breeding. In: Christou, P. & Klee, H. (eds). *Handbook of Plant Biotechnology. 2nd ed.* John Wiley & Sons Ltd, Chichester, 3–29. R

Pritchard, L., White, J.A., Birch, P.R.J. & Toth, I.K. 2006. GenomeDiagram: A python package for the visualisation of large-scale genomic data. *Bioinformatics* **22**, 616–617. J

Ramsay, G., McLean, K., Waugh, R., Spooner, D. & Bryan, G. 2006. On the domestication of potato: evidence from molecular studies. *International Solanaceae Conference and Solanaceae Genomics Network,* Madison, Wisconsin, 23–27 July 2006. P

Raven, J.A. & Karley, A.J. 2006. Carbon sequestration: Photosynthesis and subsequent processes. *Current Biology* **16**, R165–R167. J

Redpath, S., Mougeot, F., Leckie, F.M., Elston, D.A. & Hudson, P.J. 2006. Testing the role of parasites in driving the cyclic population dynamics of a gamebird. *Ecology Letters* **9**, 410–418. J

Rhind, S.M., Kyle, C.E., Riach, D.J. & Duff, E.I. 2006. Effect of nutrition on hormone profiles and patterns of deiodinase activity in the skin and associated patterns of hair follicle activity and moult in cashmere goats. *Animal Science* **82**, 723–730. J

Ritchie, M.R., MacKinnon, L., Morton, M.S., Emslie, A., Wong, V., Gilmour, A., Charlton, C., Steel, C.M., Humphris, G.M. & Gibbs, T.J. 2006. Monitoring phyto-oestrogen exposure in breast cancer patients after diagnosis.

Soy and Health Conference 2006, Düsseldorf, 12–13 October 2006. P

Ritchie, M.R., MacKinnon, L., Morton, M.S., Emslie, A., Wong, V., Gilmour, A., Currie, E.S., Steel, C.M. & Riches, A.C. 2006. Is phyto-oestrogen exposure beneficial in breast cancer patients? *Soy and Health Conference 2006,* Düsseldorf, 12–13 October 2006. P

Roberts, A.G. 2006. Confocal microscopy at SCRI; Past, present and future. *International Symposium on Applications of Plant Sciences in Emerging Scenario,* Faisalabad, Pakistan, 20–22 March 2006. P

Roberts, T.J., McKenna, S.J., Hans, J., Valentine, T.A. & Bengough, A.G. 2006. Part-based multiframe registration for estimation of the growth of cellular networks in plant roots. *18th International Conference on Pattern Recognition,* Hong Kong, 20–24 August 2006. P

Rodger, S.M., Maley, S.W., Wright, S.E., McKellar, A., Sales, J. & Buxton, D. 2005. Toxoplasmosis in sheep; the possibility of endogenous transplacental transmission. *Wiadomosci Parazytologiczne* **51 supplement**, 15–18. P

Rostoks, N., Schmierer, D., Mudie, S., Drader, T., Brueggeman, R., Caldwell, D.G., Waugh, R. & Kleinhofs, A. 2006. Barley necrotic locus *nec1* encodes the cyclic nucleotide-gated ion channel 4 homologous to the *Arabidopsis* HLM1. *Molecular Genetics and Genomics* **275**, 159–168. J

Roumet, C., Picon-Cochard, C., Dawson, L.A., Joffre, R., Mayes, R., Blanchard, A. & Brewer, M.J. 2006. Quantifying species composition in root mixtures using two methods: near-infrared reflectance spectroscopy and plant wax markers. *New Phytologist* **170**, 631–638. J

Ruiz del Castillo, M.L., Dobson, G., Brennan, R.M. & Gordon, S. 2004. Fatty acid content and juice characteristics in blackcurrant (*Ribes nigrum*) genotypes. *Journal of Agricultural and Food Chemistry* **52**, 948–952. J

Savenkov, E.I., Cowan, G.H., Ziegler, A. & Torrance, L. 2006. Cell-to-cell and systemic movement of YFP-tagged *Potato mop-top virus*. *Plasmodesmata 2006,* Pitlochry, Scotland, 30 July–3 August 2006. P

Scantlebury, M., Harris, S., Allcroft, D.J. & Hutchings, M. R. 2006. Individual trade-offs between nutrition and risk of interspecific transmission of disease by grazing: cows, badger latrines and bovine tuberculosis. *Behaviour* **143**, 141–158. J

Schena, L. & Cooke, D.E.L. 2006. Assessing the potential of regions of the nuclear and mitochondrial genome to develop a 'molecular tool box' for the detection and characterization of *Phytophthora* species. *Journal of Microbiological Methods* **67**, 70–85. J

Schena, L., Hughes, K.J.D. & Cooke, D.E.L. 2006. Detection and quantification of *Phytophthora ramorum, P. kernoviae, P. citricola and P. quercina* in symptomatic leaves by multiplex real-time PCR. *Molecular Plant Pathology* **7**, 365–379. J

Scrimgeour, C.M. 2006. Soil sampling, preparation and analysis. Second edition. By: Tan, K.H. CRC Press, Boca Raton (Book Review). *Experimental Agriculture* **42,** 124. O

Settele, J., Hammen, V., Hulme, P., Karlson, U., Klotz, S., Kotarac, M., Kunin, W., Marion, G., O'Connor, M., Petanidou, T., Peterson, K., Potts, S., Pritchard, H., Pysek, P., Rounsevell, M., Spangenberg, J., Steffan-Dewenter, I., Sykes, M., Vighi, M., Zobel, M. & Kühn, I. 2005. ALARM: Assessing LArge-scale environmental Risks for biodiversity with tested Methods. *GAIA - Ecological Perspectives in Science, Humanities, and Economics* **14**, 69–72. J

Shepherd, L.V.T., McNicol, J.W., Razzo, R., Taylor, M.A. & Davies, H.V. 2006. Assessing the potential for unintended effects in genetically modified potatoes perturbed in metabolic and developmental processes. Targeted analysis of key nutrients and anti-nutrients. *Transgenic Research* **15**, 409–425. J

Shepherd, T. & Griffiths, D.W. 2006. The effects of stress on plant epicuticular waxes. *New Phytologist* **171**, 469–499. J

Simm, G., Lewis, R.M., Young, M.J., Macfarlane, J.M., Conington, J., Navajas, E., Lambe, N.R., Bunger, L., McLean, K.A. & Glasbey, C.A. 2005. Use of CT in UK meat sheep breeding: research and practice. In *The International Skjervold Symposium 2005: Lamb Innovation*, Hamar, Norway, 2–3 June 2005. P

Sims, M., Wanless, S., Harris, M.P., Mitchell, P. I. & Elston, D.A. 2006. Evaluating the power of monitoring plot designs for detecting long-term trends in the numbers of common guillemots. *Journal of Applied Ecology* **43**, 537–546. J

Sommerhalder, R.J., McDonald, B.A. & Zhan, J. 2006. The frequencies and spatial distribution of mating types in *Stagonospora nodorum* are consistent with recurring sexual reproduction. *Phytopathology* **96**, 234–239. J

Spink, J.H., Berry, P.H., Theobald, C.M., Sparkes, D., Wade, A. & Roberts, A.M.I. 2005. The effect of location and management on the target drilling rate for winter wheat. *HGCA Project Report* **361**. T

Squire, G.R., Young, M., Brown, L., Dawson, G. & Sausse, C. 2006. Coexistence: The value of a Scottish study area within a European coordinated programme. *Proceedings of Crop Protection in Northern Britain,* Dundee, 28 February–1 March 2006, 45–50. P

Stewart, D. 2005. Can eating berries influence cardiovascular function? *Food and Health Alliance Newsletter.* **Issue 3**, 5. O

Stien, A., Bjørn, P.A., Heuch, P.A. & Elston, D.A. 2005. Population dynamics of salmon lice *Lepeophtheirus salmonis* on Atlantic salmon and sea trout. *Marine Ecology Progress Series* **290**, 263–275. J

Swanston, J.S., Newton, A.C., Hoad, S.P. & Spoor, W. 2006. Variation across environments in patterns of water uptake and endosperm modification in barley varieties and variety mixtures. *Journal of the Science of Food and Agriculture* **86**, 826–833. J

Swanston, J.S., Newton, A.C. & Smith, P.L. 2006. Grain quality characters in complex mixtures of soft wheat and acknowledgement by farmers and distillers. *COST 860 SUSVAR Workshop on Cereal Crop Diversity: Implications for Production and Products,* La Besse, France, 12–15 June 2006. P

Theobald, C.M., Roberts, A.M.I., Talbot, M. & Spink, J. H. 2006. Estimation of economically optimum seed rates for winter wheat from series of trials. *Journal of Agricultural Science* **144**, 303–316. J

Thomas, W.T.B. 2006. Application of biotechnology to cereal breeding in the UK. *Proceedings of Crop Protection in Northern Britain,* Dundee, 28 February–1 March 2006, 95–100. P

Tilsner, J., Roberts, A.G. & Oparka, K. 2006. Using a crippled virus to screen for non-cell autonomous proteins. *Plasmodesmata 2006,* Pitlochry, 30 July–3 August 2006. P

Torrance, L. 2004. Antibody and nucleic acid based techniques. In: Lapierre, H. & Signoret, P. (eds). *Virus Diseases of Poaceae (Gramineae).* INRA Editions, Paris, 99-108. R

Torrance, L. & Koenig, R. 2004. *Furovirus*. In: Fauquet, C.M., Mayo, M.A., Maniloff, J., Desselberger, U. & Ball, L.A. (eds). *Virus Taxonomy, Classification and Nomenclature of Viruses.* Elsevier, Amsterdam, 1027–1032. R

Torrance, L., Andreev, I.A., Gabrenaite-Verhovskaya, R., Cowan, G.H., Mäkinen, K. & Taliansky, M.E. 2006. An unusual structure at one end of potato potyvirus particles. *Journal of Molecular Biology* **357**, 1–8. J

Torrance, L., Cowan, G.H., Gillespie, T., Ziegler, A. & Lacomme, C. 2006. Barley stripe mosaic virus-encoded proteins triple-gene block 2 and γb localize to chloroplasts in virus-infected monocot and dicot plants, revealing hitherto-unknown roles in virus replication. *Journal of General Virology* **87**, 2403–2411. J

Torrance, L., Cowan, G.H., Zeigler, A., Gillespie, T. & Savenkov, E.I. 2006. Comparison of subcellular interactions of the TGB2 movement proteins of *Potato mop-top* and *Barley stripe mosaic viruses* reveals subtle differences and an association with sites of virus replication. *Plasmodesmata 2006,* Pitlochry, 30 July–3 August 2006. P

Torrance, L., Ziegler, A., Pittman, H., Paterson, M., Toth, R. & Eggleston, I. 2006. Oriented immobilisation of engineered single-chain antibodies to develop biosensors for virus detection. *Journal of Virological Methods* **134**, 164–170. J

Toth, I.K., Hyman, L.J., Moleleki, L.N., Ravensdale, M., Robert, C., Liu, H., Humphris, S.N., Hedley, P.E., Gilroy, E., Pritchard, L. & Birch, P.R.J. 2006. What has genomics ever done for us? A study of *Erwinia* and blackleg disease. *Proceedings of Crop Protection in Northern Britain,* Dundee, 28 February–1 March 2006, 239–242. P

Toth, I.K., Pritchard, L. & Birch, P.R.J. 2006. Comparative genomics reveals what makes an enterobacterial plant pathogen. *Annual Review of Phytopathology* **44**, 305–336. J

Traykova, A., Ziegler, A. & Hristova, D. 2006. Diagnostics of *Bean common mosaic* virus in common bean (*Phaseolus vulgaris* L.). *Annual Balkan Week of Plant Health,* Kostinbrod, Bulgaria, 28–31 May, 2006. P

Tuomainen, M.H., Nunan, N., Lehesranta, S.J., Tervahauta, A.I., Hassinen, V.H., Schat, H., Koistinen, K.M., Auriola, S., McNicol, J.W. & Kärenlampi, S.O. 2006. Multivariate analysis of protein profiles of metal hyperaccumulator *Thlaspi caerulescens* accessions. *Proteomics* **6**, 3696–3706. J

Tzortzakakis, E.A. & Trudgill, D.L. 2005. A comparative study of the thermal time requirements for embryogenesis in *Meloidogyne javanica* and *M. incognita*. *Nematology* **7**, 313–315. J

Valentine, T.A., Binnie, K. & Bengough, A.G. 2005. Role of border cells in root growth and rhizosphere interactions. *Society for Experimental Biology – Plant Frontier Meeting,* Sheffield, 21–23 March 2005. P

Valentine, T.A., Binnie, K., Hans, J., McKenzie, B.M. & Bengough, A.G. 2006. Root growth responses to soil physical properties. *14th New Phytologist Symposium,* The Royal Society, London, 23–24 January 2006. P

Valentine, T.A., Binnie, K., Hans, J., McKenzie, B.M. & Bengough, A.G. 2006. Root responses to soil physical conditions. *UMPIRE Meeting,* Prague, April 2006. P

Valentine, T.A., Binnie, K., Stubbs, V. & Bengough, A.G. 2004. Function of root border cells in root-soil interactions explored by genetic analysis. *Proceedings of the 14th Congress of the Federation of European Societies of Plant Biology,* Krakow, Poland, 23–27 August 2004. P

Valentine, T.A., Binnie, K., Stubbs, V. & Bengough, A.G. 2004. Genetic analysis of the role of root border cells and mucilage in plant soil interactions. *Rhizosphere,* Munich, Germany, 12–17 September 2004. P

Valentine, T.A., Karley, A.J., Binnie, K., Post, J., Young, M., Wright, G.M., Marshall, B., Hallett, P.D., McKenzie, B.M. & Bengough, A.G. 2006. Plant growth responses to soil physical constraints. *ESF – Wellcome Trust Conference,* Cambridge, 8–11 November 2006. P

Valentine, T.A., Shaw, J., Blok, V.C., Phillips, M.S., Oparka, K. & Lacomme, C. 2004. Virus induced silencing of root function genes using a modified tobacco rattle virus. *Plasmodesmata 2004 5th International Conference,* Pacific Grove, California, USA, 17–21 August 2004. P

van de Graaf, P., Danial, J., Saddler, G.S., Parkinson, N.M., Elphinstone, J.G., Winfield, M.O. & Bryan, G.J. 2006. Potato brown rot: An analysis of the risk to seed crops in Scotland. *Proceedings of Crop Protection in Northern Britain,* Dundee, 28 February–1 March 2006, 233–238. P

van Os, H., Andrzejewski, S., Bakker, E., Barrena, I., Bryan, G.J., Caromel, B., Ghareeb, B., Isidore, E., De Jong, W., van Koert, P., Lefebvre, V., Milbourne, D., Ritter, E., van der Voort, J.N.A.M.R., Rousselle-Bourgeois, F., van Vliet, J., Waugh, R., Visser, R.G.F., Bakker, J. & van Eck, H. 2006. Construction of a 10,000 marker ultradense genetic recombination map of potato: providing a framework for accelerated gene isolation and genomewide physical map. *Genetics* **173**, 1075–1087. J

Venkatesh, B., Babujee, L., Liu, H., Hedley, P.E., Fujikawa, T., Birch, P.R.J., Toth, I.K. & Tsuyumu, S. 2006. *Erwinia chrysanthemi* 3937 PhoQ sensor kinase regulates several virulence determinants. *Journal of Bacteriology* **188**, 3088–3098. J

Walker, D.M. & Marion, G. 2006. Selecting nonlinear stochastic process rate models using information criteria. *Physica D: Nonlinear Phenomena* **213(2)**, 190–196. J

Walker, D.M., Pérez-Barbería, F.J. & Marion, G. 2006. Stochastic modelling of ecological processes using hybrid Gibbs samplers. *Ecological Modelling* **198**, 40–52. J

Walker, P.G., Pont, S.D.A., Viola, R. & Hancock, R.D. 2006. L-ascorbic acid accumulation in fruit of blackcurrant (*Ribes nigrum* L.). *Proceedings of the 15th Congress of the Federation of European Societies of Plant Biology,* Lyon, France, 17–21 July 2006. P

Walters, D.R., Newton, A.C. & Lyon, G.D. 2006. Induced resistance: when will the potential be fully realised in practice? *Proceedings of Crop Protection in Northern Britain,* Dundee, 28 February–1 March 2006, 169–174. P

Waugh, R. 2006. Illumina technology and barley genomics. *ESF – Wellcome Trust Conference,* Cambridge, 8–11 November 2006. P

Waugh, R., Leader, D.J., McCallum, N. & Caldwell, D. 2006. Harvesting the potential of induced biological diversity. *Trends in Plant Science* **11**, 71–79. J

Webster, R., Welham, S.J., Potts, J.M. & Oliver, M.A. 2006. Estimating the spatial scales of regionalized variables by nested sampling, hierarchical analysis of variance and residual maximum likelihood. *Computers and Geosciences* **32**, 1320–1333. J

Werhli, A.V., Grzegorczyk, M. & Husmeier, D. 2006. Comparative evaluation of reverse engineering gene regulatory networks with relevance networks, graphical Gaussian models and Bayesian networks. *Bioinformatics* **22**, 2523–2531. J

Werhli, A.V., Grzegorczyk, M., Chiang, M.T. & Husmeier, D. 2005. Improved Gibbs sampling for detecting mosaic structures in DNA sequence alignments. *Statistics in Genomics and Proteomics*, Centro Internacional de Matematica, Coimbra, Portugal, 5 October 2005. R

Werhli, A.V., Grzegorczyk, M., Husmeier, D. & Urfer, W. 2006. Comparative evaluation of the accuracy of reverse engineering gene regulatory networks with various machine learning methods. *Conference on Intelligent Systems for Molecular Biology*, Fortaleza, Brazil, 6–10 August 2006. P

Wheatley, R.E., Mitchell, S.M., Davidson, J.A. & Daniell, T. 2006. Spatio–temporal relationships between nitrification rates and physical and chemical parameters in a soil growing barley. *11th International Symposium on Microbial Ecology,* Vienna, Austria, 20–25 August 2006. P

White, P.J., Broadley, M.R. & Hammond, J.P. 2006. Natural genetic variation in plant mineral concentrations. *Plant Nutrition meets Plant Breeding. First Joint Conference of the German Society for Plant Nutrition and the Research Centre for Biotechnology and Plant Breeding, University of Hohenheim,* Stüttgart, Germany, 26–28 September 2006. P

White, P.J., Broadley, M.R. & Hammond, J.P. 2006. Natural genetic variation in plant mineral concentrations. *Plant Transport Group Meeting,* Wye, 4–6 September 2006. P

Whybrow, S., Harrison, C.L.S., Mayer, C-D. & Stubbs, R.J. 2006. Effects of added fruits and vegetables on dietary intakes and body weight in Scottish adults. *British Journal of Nutrition* **95**, 496–503. J

Winfield, M., D'Amato, G.F., De Dominicis, R.I., Salimbeni, P. & Tucci, G.F. 2006. A cytological and molecular study of the genera *Scorzonera* L. and *Podospermum* (L.) D.C. (Asteraceae). *Caryologia* **59**, 153–163. J

Winfield, M., Lloyd, D., Griffiths, D.W., Bradshaw, J.E., Muir, D., Nevison, I.M. & Bryan, G.J. 2005. Assessing organoleptic attributes of *Solanum tuberosum* and *S. phureja* potatoes. *Aspects of Applied Biology,* **76**, 279–308. P

Winfield, M., van der Graaf, P., Reid, A., Saddler, G. & Bryan, G.J. 2006. Genetic diversity in *Solanum dulcamara* populations along Scottish rivers. *International Solanaceae Conference and Solanaceae Genomics Network,* Madison, Wisconsin, 23–27 July 2006. P

Wood, M., Jolliffe, I.T. & Horgan, G.W. 2005. Variable selection for discriminant analysis of fish sounds using matrix correlations. *Journal of Agricultural, Biological and Environmental Statistics* **10**, 321–336. J

Wright, K.M. & Oparka, K.J. 2006. The ER within plasmodesmata. In: Robinson, D.G. (ed.). *The Plant Endoplasmic Reticulum.* Springer Verlag, Heidelberg, 279–308. R

Wright, K.M., Chapman, S. & Oparka, K.J. 2006. What are you doing to me? The effect of commonly used inhibitors on tobacco epidermal cell structure. *Plasmodesmata 2006,* Pitlochry, Scotland, 30 July–4 August 2006. P

Yeates, G.W. & Boag, B. 2006. Female size shows similar trends in all clades of the Phylum Nematoda. *Nematology* **8**, 111–127. J

Yeates, G.W. & Boag, B. 2006. Small and large females occur in all nematode clades. *New Zealand Parasitology Conference,* Palmerston North, 17 December 2006. P

Zhan, J., Jones, E. & Newton, A.C. 2006. Factors associated with the race compositions of *Rhynchosporium secalis* in United Kingdom: meta-analyses from historic surveys. *3rd International Barley Leaf Blight Workshop,* Edmonton, Canada, 23–27 July 2006. P

Zhan, J., Marshall, B. & Newton, A.C. 2006. Quantitative evolution of pathogen aggressiveness under two-cultivar mixtures. *Phytopathology* **96**, S129. P

Zhan, J., Stefanato, F.L. & McDonald, B.A. 2006. Selection for increased cyproconazole tolerance in *Mycosphaerella graminicola* through local adaptation and in response to host resistance. *Molecular Plant Pathology* **7**, 259–268. J

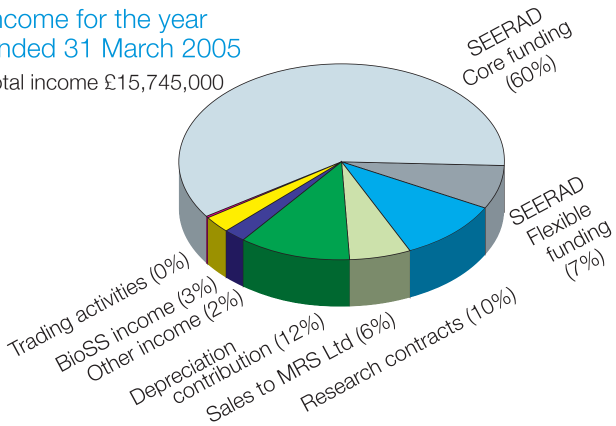
Zhan, J. & McDonald, B.A. 2006. Significant difference in virulence between *MAT1-1* and *MAT1-2* isolates in the wheat pathogen *Mycosphaerella graminicola*. *Phytopathology* **96**, S129. P

Zhang, X., Johnson, S.N., Gregory, P.J., Crawford, J.W., Young, I.M., Murray, P.J. and Jarvis, S.C. 2006. Modelling the movement and survival of the root-feeding clover weevil, *Sitona lepidus,* in the root-zone of white clover. *Ecological Modelling* **190,** 133-146. J

Accounts

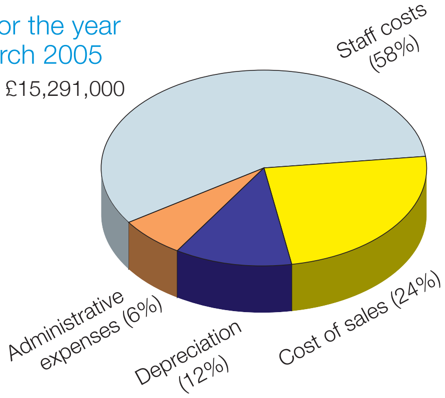
Income for the year ended 31 March 2005

Total income £15,745,000



Expenditure for the year ended 31 March 2005

Total expenditure £15,291,000



Balance sheet at 31 March 2005

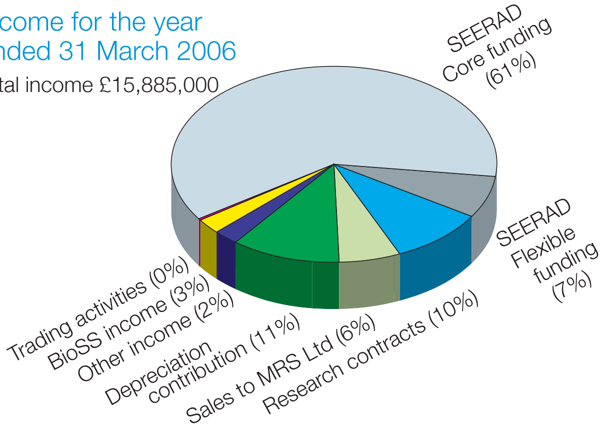
Total value £28,802,000

Assets	
Fixed assets	94 %
Stocks	0 %
Debtors	6 %

Liabilities	
Capital reserve	86 %
Income & expenditure account	4 %
Current liabilities	10 %

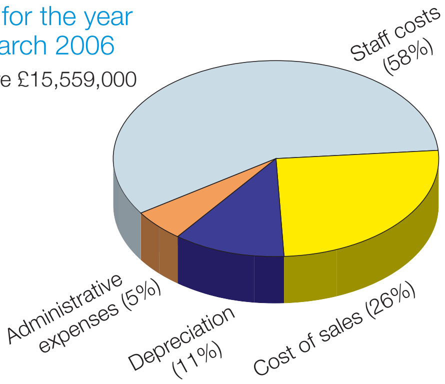
Income for the year ended 31 March 2006

Total income £15,885,000



Expenditure for the year ended 31 March 2006

Total expenditure £15,559,000



Balance sheet at 31 March 2006

Total value £28,936,000

Assets	
Fixed assets	95 %
Stocks	0 %
Debtors	5 %

Liabilities	
Capital reserve	85 %
Income & expenditure account	5 %
Current liabilities	10 %

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

Distinctions and Awards

Feb 2006

Prof John Raven was awarded Honorary Life membership of the British Phycological Society.

Dr Paul Birch was made 'Extra-ordinary Professor' of the University of Pretoria, South Africa.

April 2006

Prof Frank Gunstone, honorary research fellow at SCRI and a consultant to MRS, received the Chang Award of the American Oil Chemists' Society in St Louis. This is one of their premium awards and is given to those that assist the Oils and Fats Industry. It carries a substantial cash prize and a jade statue.

June 2006

Paul Baird from Glasshouse & Field Services was awarded the NFU (Ingliston) Prize for the Best Part-time Student (SVQ Level 3) from Oatridge College at the Annual Award Ceremony. The prize was presented by George Anderson, former Head of the Royal Botanic Garden Edinburgh's School of Horticulture.

Birthday Honours 17th June Mike De,Maine MBE.

August 2006

Dr Alison Lees won the Peter Massalski prize for meritorious research conducted by an SCRI scientist under 36 years of age. Dr Stuart Wale, the chairman of the Scottish Society for Crop Research, presented the prize at Potatoes in Practice.

The 25th Mylnefield Shield Golf tournament was won by Bob Lowe.

George Anderson presents Paul Baird with his prize.

Alison Lees receives the Massalski prize from Stuart Wale.

Ronnie Forbes and Peter Gregory as an artwork.

September 2006

Peter Gregory, Howard Davies, Robbie Waugh and John Brown were awarded Honorary Professorships at Glasgow University.

The Leverhulme Trust awarded a grant to SCRI for Professor Ronnie Forbes to be Artist-in-Residence for 18 months. Ronnie is a painter and film-maker with more than 30 solo exhibitions.

Higher Degrees

Mohamed Adam. PhD University of Dundee. Molecular variation in root knot nematodes (*Meloidogyne* spp.) from the Mediterranean region.

Yousuf Akhond. PhD University of Dundee. Biolistic DNA delivery into tobacco male gametophytes and its consequences.

Laurence Ducreux. PhD University of Dundee. Manipulation of carotenoid metabolism in tubers of *Solanum tuberosum* and *S. phureja* using an antisense approach.

Luca Mazzitelli. PhD University of Dundee. Physiological, biochemical and molecular characterization of bud dormancy in woody perennial species.

Wayne Morris. PhD University of Dundee. Characterisation and manipulation of gene expression during carotenogenesis in potato tubers.

Sanjeev Kumar Sharma. PhD University of Dundee. Development of an efficient somatic embryogenesis system for developing synthetic seeds in potato

Konstantina Stamati. PhD University of Dundee. A study of the population genetics of *Salix lanata*, *S. lapponum* and *S. herbacea* across Scotland.

Noelani van den Berg. PhD University of Pretoria, South Africa. Identification of genes associated with tolerance in the Cavendish banana selection GCTCV-218 against *Fusarium oxysporum* F.sp. *cubense* 'subtropical' race 4'.

Staff List as at 1 October 2006

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

Genetics

R Waugh BSc PhD (Programme Leader)[3,4]
J Alexander BSc
M M Bayer MSc PhD
S F Blackie BSc
N Bonar HNC
A Booth HNC
C Booth BSc
J E Bradshaw MA MSc PhD [3]
R M Brennan BSc PhD
J W S Brown BSc PhD [3,4,13]
G J Bryan BSc PhD
X Chen BSc PhD
G P Clark HNC BSc
M F B Dale BSc PhD[3]
D Davidson
L Donnelly
A Druka MSc PhD
B P Forster BSc PhD[3]
J D Fuller
S L Gordon HNC
J Graham BSc PhD
B Harrower HND BSc MSc
P Hedley BSc PhD
I Hein MSc PhD
L Jorgensen HND
R Keith NEBS
S H Kim BSc PhD
D P King BSc
D J Leader BSc PhD
D Lewandowska BSc
M S Liney HND
J Liu BSc MSc PhD
D C Lloyd BSc MSc
K Loades BSc
J Lyon
N McCallum BSc
G McKenzie HND BSc
K McLean BSc
J McNicoll HNC 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
S Mudie BSc
M Myles ONC
D Nwankwo BSc MSc
G Ramsay BSc PhD[3]
L Ramsay BSc PhD
D M Roberts HND 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
J N Squires BSc PhD
G E L Swan
J S Swanston BSc PhD CBiol MIBiol
W T B Thomas BSc PhD
I M Tierney BSc MSc
G Wilde
S L Williamson BSc
R N Wilson NCH
M R Woodhead BSc PhD
G R Young HNC

Dundee University Group 1

A J Flavell BSc PhD (Principal Investigator)
R Jing BSc PhD
J Lee BSc PhD
M Lyons BSc
N H Syed BSc PhD

Dundee University Group 2

C Halpin BSc MSc HDip PhD (Principal Investigator)
A Barakate BSc PhD
E Douglas BSc
A Goldie BSc
S Haupt BSc PhD
J Searle BSc

Dundee University Group 3

G G Simpson BSc PhD (Principal Investigator)
J Marshall BSc DPhil
L Terzi BSc MSc PhD

Mylnefield Research Services

D Coyle
G Duncan BSc
L Ferguson
S N Jennings BSc
G Reid BSc

Plant Pathology

L Torrance BSc PhD (Programme Leader)[3]
M Armstrong BSc PhD
A O Avrova BSc PhD
P R J Birch BSc PhD
V C Blok BSc MSc PhD
P Boevink BSc PhD
J L Brierley BSc PhD
W Burry
M Burton
T Canto BSc PhD
S N Chapman BSc PhD
D E L Cooke BSc PhD
G H Cowan HNC MSc
A Dolan HNC
B Fenton BSc PhD CBiol MIBiol[3]
G L Fraser
E Gilroy BSc PhD
S C Gordon HNC[3]
D C Guy HND
J Heilbronn HNC BSc PhD
A M Holt
C Hornyik BSc PhD
S N Humphris HNC BSc PhD
J T Jones BSc PhD[3]
L Kasprowicz BSc
A Kumar BSc PhD
C Lacomme BSc PhD
S S Lamond
M J M Latijnhouwers BSc PhD
A K Lees BSc PhD
H Liu BSc MSc PhD
G D Lyon BSc MSc DIC PhD[3]
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
M S Phillips BSc[3]
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
R M Solomon-Blackburn BA MSc
J Stephens BSc PhD
J A Stewart HND BSc
L Sullivan BSc
M M Swanson BSc PhD
M Taliansky PhD DSc[11]
I K Toth BSc PhD[6]
E Warden ONC
S Whisson BSc PhD
N A Williams HNC
K M Wright MA PhD
K Wypijewski MSc PhD
V Young BSc
J Zhan BSc MSc 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 Fellow, Rothamsted Research
[16] Visiting Prof University of Stirling
[17] Adjunct Professor, University of Canterbury New Zealand
[18] Special Professor, University of Nottingham
[19] Visiting Associate Professor, Cornelius University Bratislava

Quality Health & Nutrition

D Stewart BSc PhD (Programme Leader)
M G Anderson MSc BSc
S C Conner BSc MSc CChem MRSC
H V Davies BSc PhD CBiol FIBiol[1,2,4]
G Dobson BSc PhD
P M Dobson
L J M Ducreux BSc MSc MPhil PhD
D W Griffiths MA PhD CChem MRSC
R D Hancock BSc PhD
R Hutchison
G J McDougall BSc PhD
D McRae ONC
N Marquis BSc

W L Morris BSc MSc PhD
P Neave NC
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
J A Sungurtas HND
M A Taylor BSc PhD
S R Verrall HNC
P G Walker HND
J F Wilkie

Mylnefield Research Services

G Birch BSc AMRSC
W C Christie MBE BSc PhD DSc FRSE
A Ferguson BSc
F Gunstone BSc PhD DSc FRSE
L Hunter BSc
R Razzo BSc
S Rowbottom ONC HNC BSc CChem MRSC
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
D Cullen BSc PhD
T J Daniell BSc PhD[3]
J Davidson BSc
M J Elliott BSc
F Falconer HNC
L Ford BA
T S George BSc PhD
D C Gordon HNC
B S Griffiths BSc PhD[3]
P D Hallett BSc PhD
C Hawes BSc PhD
D W Hopkins BSc PhD CBiol FIBiol

R W Humphry BSc PhD
P P M Iannetta BSc PGCE(S) PhD
S N Johnson BSc DPhil
A J Karley BA DPhil
J McCluskey BSc
B M McKenzie BSc PhD
B Marshall BSc PhD ARCS
C Mitchell BSc
S M Mitchell BSc
R Neilson HNC MSc PhD
M Opik
A Parish BSc
J Post
S Regan BSc MSc
C M Scrimgeour BSc PhD[3]
G R Squire BA PhD
W M Stein HNC BSc
J A Thompson BSc
T Valentine BSc PhD
R E Wheatley BSc PhD

J Wishart BSc PhD
G M Wright HNC
N Wuyts BSc MSc PhD
M Young HND MSc PG Dip IT

Dundee University Group 4

H G Jones MA PhD FIHort (Principal Investigator)
I Leinonen PhD
S Pisanu PhD
R Ramsey BSc PhD
P Schofield BSc PhD
L Spencer BSc
O Stasyk PhD
N Turnbull

Dundee University Group 5

J A Raven BA PhD HonPhD(Umea) CBiol FIBiol FRS FRSE
(Principal Investigator)
E McCarvill
V Moorcroft
J Stewart

Communication and Information Services

S E Stephens BSc MA MCLIP (Acting Head)
K S Athwal BSc
U M McKean MA DipLib

S F Malecki ABIPP
S J Neilson DipBiolSci DipPollCon BSc
I R Pitkethly HND

D Third
S K Thomson HND BA

Information Technology

S Clark HNC MSc (Head of IT)
L H Davidson BA
P J R Grimmond BA

R McCreary BSc
L A McGregor BSc

M Petrie 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 MCIPD
R G Davidson
M J De,Maine MBE BSc MPhil (Health and Safety Co-ordinator)
P Duncan
S Forsyth

K L Grant BA
B V Gunn
S Inglis
J Keith
L MacDonald BA CA
K Muir
A Pack BA

W Patterson HND
M Pearson BSc
K Robb
A Sandilands
S Smart
E L Stewart
L Young

Engineering and Maintenance

S Petrie BSc (Head of Engineering and Maintenance)
J Anderson
D Byrne
C Conejo
R Craik
G J E Ewart
A G Fox
D Gray HNC
K A Henry
E Lawrence
A Low MBE
R D McLean
I C McNaughton HNC
E Millar
G Pugh
D J Redford
G C Roberts
J Rowe
W Scott
B Semple
M J Soutar
B Ward

Glasshouse and Field Services

P A Gill HND NEBOSH
(Glasshouse and Field Services Manager)
J Abernethy
P Baird
R Balfour
J R K Bennett
J T Bennett
E Caldwell
C A Cuthill NC
A G Dobson HNC HND
B Fleming
I Fleming
J M Ford
A C Fuller
M A Grassie HNC BEd
D J Harkins
P Heffell ONC
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 Williams
D Young

Mylnefield Research Services

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

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]
S M Bierman BSc MSc
A Butler BSc PhD
J M Dickson BSc
D Glancy
E M Heyburn MA
D Husmeier BSc PhD
M A M Kirkwood DA
K Lin BSc PhD
A D Mann BSc
G R Marion BSc MSc PhD
I J McKendrick BSc PhD
I M Nevison MA
A M I Roberts BSc MSc
J Sales BSc MSc

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

J W McNicol BSc MSc (Head of Group)[3]
C A Hackett BA DipMathStats PhD
K M MacKenzie BSc MSc PhD
N Massat MRes MSc PhD
F G Wright BSc MSc PhD

Short-term visiting workers

Name	Country of origin	Programme	Month/yr of arrival	Length of stay
S Anderson	UK	EPI	Sep-06	7 mths
N Azeez	India	GEN	May-06	5 mths
E Bailey	UK	EPI	Oct-06	6 mths
S Bairner	UK	EPI	Oct-06	6 mths
B Barclay	UK	EPI	Jul-06	1 mth
S Benali	India	GEN	May-06	5 mths
L Bi	China	EPI	Feb-06	2 mths
W Brockie	UK	GEN	Sep-05	7 mths
N Champouret	Netherlands	PP	Apr-06	1 mth
L Chesnau	France	EPI	Jun-06	3 mths
J Chiffoleau	France	QHN	Jun-06	2 mths
E Clark	UK	EPI	Sep-06	1 mth
A Confraria	Portugal	PP	Oct-06	1 mth
V Delessy	France	EPI	Jul-06	2 wks
H Deng	China	EPI	Oct-05	7 mths
B Desantis	Italy	BioSS	May-06	1 mth
L Du	UK	GEN	May-06	3 mths
V Dubois	France	PP	Jul-06	5 mths
G Fernandez	Spain	PPI	Sep-06	8 mths
A M Gbadegesin	Nigeria	DU	Apr-06	1 mth
P Gerard	UK	EPI	Aug-06	1 wk
G Girsey	Hungary	PP	Apr-06	2 wks
T Godfrey	UK	EPI	Oct-06	6 mths
J Hesketh	UK	EPI	Oct-05	6 mths
P N Hoebe	Netherlands	GEN	Jul-06	5 mths
S Holland	UK	GEN	Jun-06	3 mths
M Hutchison	UK	QHN	Jul-06	1 mth
M Ikeji	UK	QHN	May-06	4 mths
C Jamar	Belgium	GEN	Feb-06	6 mths
N Kalinina	Russia	PP	Aug-06	3 mths
A King	UK	GEN	May-06	1 wk
M Landova	Czech Republic	EPI	Jun-06	3 wks
H Li	China	EPI	Jan-06	3 mths
M Liu	China	EPI	Dec-05	3 mths
J Liu-Clarke	China/Norway	EPI	Jan-06	5 mths
M McAlister	UK	PPI	Sep-06	8 mths
H McLellan	UK	PP	Oct-06	1 mth
I Mirowska	Poland	PP	Nov-05	5 mths
J Morris	UK	QHN	Jul-06	1 mth
O Ngulu	Tanzania	GEN	Oct-06	6 mths
E Obraztsova	Russia	PP	Aug-06	2 mths
C Pernin	France	EPI	Jul-06	3 mths
C Plain	UK	PP	Oct-06	6 mths
K Polok	Poland	DU	Jun-06	1 mth
S Praveen	India	PP	Sep-06	3 mths
D Rakitina	Russia	PP	Jun-06	4 mths
G Rodio	Italy	GEN	Oct-05	6 mths
U Saks	Estonia	EPI	May-06	2 wks
E Savenkov	Russia	PP	Apr-06	12 mths
P Schaefer	Germany	PP	Feb-06	1 mth
M Schmeer	Germany	EPI	Feb-06	2 wks
M Skelton	Ireland	PP	Jun-06	2 mths
J Sliwka	Poland	PP	Jan-06	2 wks
E Temu	Tanzania	GEN	Oct-06	6 mths
H Toktay	Turkey	PP	Jan-06	1 mth
F Van Gissegem	Belgium	EPI	Jun-06	3 wks
S Vivera	India	QHN	May-06	5 mths
A Vollsnes	Norway	EPI	Apr-06	3 mths
A Weir	UK	EPI	Oct-06	6 mths
E Wilson	UK	PP	Jan-06	1 mth
S Yao	China	EPI	Jan-06	2 mths
B Zhang	China	EPI	Nov-05	3 mths
X Zhang	UK	EPI	Nov-05	5 mths

Longer-term visiting workers

Name	Country of origin	Programme	Month/yr of arrival	Length of stay
R Campbell	UK	QHN	Aug-06	3 yrs
K Clark	UK	EPI	Oct-06	3 yrs
E Coates	UK	QHN	Sep-06	3 yrs
S Grouffaud	UK	PP	Oct-06	3 yrs
D Hardy	France / UK	PP	Aug-06	3 yrs
J Hillier	UK	EPI	Aug-05	1 yr
P Hudacsek	Hungary	EPI	Oct-05	3 yrs
C Kadu	Africa	GEN	Feb-06	1 yr
E Lascaux	France	PP	Jun-04	3 yrs
N Liu	China	EPI	Jul-06	1 yr
B Michovski	UK	EPI	May-04	3 yrs
S Scibetta	Italy	PP	Mar-05	2 yrs
M Shams-Bakhsh	Iran	GEN	Oct-05	1 yr
M Skinnader	Ireland	EPI	Sep-06	3 yrs
R Sonnenberg	UK	EPI	May-04	3 yrs
S Vink	Netherlands	EPI	Oct-06	3 yrs
H Xiao	UK	QHN	Sep-06	3 yrs

Honorary Research Fellows

Professor Richard Abbott BSc PhD
Dr Pamela Anderson PhD
Dr Hugh Barker BSc PhD
Professor Geoffrey J Barton BSc PhD
Dr Bill Belknap PhD
Professor Jill J F Belch MD(Hons) FRCP FAcadMedSci
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
Dr Tim Close PhD
Professor John Crawford BSc PhD
Professor Michael C R Davies BSc DipTheol MPhil PhD CEng MICE FTG
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 FIBiol FLS
Professor Mary Gibby BSc PhD FRSE FRSA
Professor Frank Gunstone BSc PhD DSc FRSC FRSE
Dr Claire Halpin BSc MSc H Dip PhD
Dr Linda Handley BA BEd MSc PhD
Professor Bryan Harrison CBE BSc PhD DAgFor FRS FRSE
Dr John Hayes BSc PhD
Professor Andreas Graner BSc PhD
Professor John Hillman BSc PhD DSc FLS CBiol FIBiol FIHort FCMI SHM FRAgS FRSE
Dr Pete Hollingsworth BSc PhD
Dr Steve Hubbard MSc DIC(London) DPhil (Oxon)
Professor Andrew Hudson BSc PhD
Professor Lindsey Innes OBE BSc PhD DSc FRSE
Professor Hamlyn Jones MA PhD FIHort
Dr A Teifion Jones BSc PhD
Professor Peter Langridge BSc PhD
Dr Gary Loake 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 FIBiol
Dr Donald K L MacKerron MBE BSc PhD
Dr Mike Mayo BSc PhD
Professor Tom Meagher BA PhD
Professor Andrew J Millar BA PhD
Professor Tim A Newson BSc PhD
Professor Hugh Nimmo MA PhD FRSA
Professor Karl Oparka BSc PhD
Dr Michel Perombelon MBE PhD MSc BSc Dip Agric
Professor Wayne Powell BSc MSc PhD DSc
Professor John Raven BA PhD HonPhD(Umea) CBiol FIBiol FRS FRSE
Dr David J Robinson MA PhD
Professor David J Robinson BSc PhD
Mr Jean-Marc Rotsaert
Professor Karel Schubert PhD
Professor David M Spooner PhD
Professor Janet Sprent OBE BSc DSc PhD ARCS FRSE
Dr Alyson Tobin BSc PhD
Dr David L Trudgill MBE BSc PhD FIBiol
Dr Pieter van West MSc PhD
Professor Roberto Viola DipAgrSci PhD
Mr David Walker OBE
Dr Brian Williamson BSc MSc PhD DSc
Dr Roger Wise BSc PhD
Professor Iain Young BSc PhD

Postgraduate Students

Name	Programme	Project Title
Gillian Banks	EPI	Dynamics of feral oilseed rape populations and the impacts on associated insect communities.
Raymond Campbell	QHN	Genetics of carotenoid levels in potato tubers.
Emily Clark	EPI	Multi-trophic factors influencing aphid vector competence in a spatially heterogenous environment.
Katy Clark	EPI	Does Mother know best? Is host plant selection by above ground insects influenced by below ground herbivores.
Emma Coates	QHN	Anti-cancer effects of soft fruit phytochemicals.
Jordi Comadran Trabal	GEN	Mapping adaptation of barley to drought environments (MABDE).
Sean Conner	QHN	Metabolic profiling of potato (*Solanum tuberosum*).
Suzanne Donn	EPI	Molecular ecology of soil nematode communities.
Martin Elliot	EPI	On modelling GM oilseed rape populations.
Dominique Hardy	PP	Biofilm formation by *Pectobacterium atrosepticum* on potato tubers.
Gerald Hochshartner	GEN	Application of a novel snoRNA marker system in plant evolution and systematics.
Severine Grouffaud	PP	Translocation of *Phytophthora* effectors and their manipulation of host plant disease resistance.
Louise Kasprowicz	PP	The population dynamics and ecophysiology of the peach-potato aphid *Myzus persicae.*
Jennifer Kennedy	EPI	AM fungi in agriculture.
Susan McCallum	GEN	Linking phenotype to genotype for fruit quality traits in raspberry.
Sandy MacDonald	GEN	Regulatory pathways involving iron acquisition in *Pasteurella multocida* A:3, their role in pathogenesis and relevance to disease mechanisms in *Pectobacterium atrosepticum.*
Tim Miller	PP	Metabolic and proteomic profiling of the interaction between plant hosts and root knot and cyst nematode endophytes.
Carolyn Mitchell	PP	Cane fruit: Novel approaches for ICM in fresh and processed crops.
Lucy Moleleki	PP	Characterization of the interaction between type three secreted proteins in *Pectobacterium atrosepticum* and its host plant *Solanum tuberosum* L.
Juan Gonzalo Morales Osorio	PP	Mechanisms of virulence and avirulence in the biotrophic interaction between potato and the late blight pathogen *Phytophthora infestans.*
Michael Ravensdale	PP	Unravelling the regulatory mechanisms involved in the production of coronafacoyl phytotoxins and other pathogenicity determinants in *Pectobacterium atrosepticum.*
Christelle Robert	BioSS	Elucidation of the regulatory binding sites in bacterial genomes.
Rosalind Taylor	PP	Ubiquitin-proteasome directed proteomic approach to dissect biotic stress signalling in plants.
Maja Thorsen	EPI	Biological mechanisms involved in stabilizing sandy soils of the Machair.
Stefanie Vink	EPI	Functional soil ecology and conservation in the Machair in relation to changing land management.
Tobias Wojciechowski	EPI	Root development in semi-dwarfing lines of wheat and barley.
Han Xiao	QHN	Function of polyphenols in chemoprevention.

SCRI Research Programme ongoing as at 1 October 2006

The research programme is commissioned by SEERAD and a variety of other funders. The list contains the body that awarded this grant and the title of the project and, in the case of SEERAD, the commissioning number.

SEERAD 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

SEERAD Flexible Fund

SCR/589/02	Novel methodologies and tools for the analysis of germplasm collections.
SCR/842/02	Elucidation of regulatory and signalling networks that control bacterial disease development.
SCR/906/03	Factors affecting the prevalence of clones of *Myzus persicae* in Scotland, particularly those with aphicide resistance, and implications for virus control in seed potatoes.
SCR/907/03	Viral-based functional genomics of the Golgi apparatus.
SCR/908/03	Post-genomic analysis of *Erwinia carotovora* virulence responses in *in vitro* and *in planta* environments.
SCR/909/04	Function of the exon junction complex in the plant nucleolus.
SCR/910/04	The genetics of gene expression in barley.
SCR/913/05	Characterisation and development of gene silencing in *Phytophthora infestans* for high-throughput determination of gene function.
SCR/915/06	Limiting the risk from *Phytophthora idaei* to the Scottish raspberry industry.
SCR/917/06	A review of the health benefits of oats.
BSS/842/04	Elucidation of regulatory and signalling networks that control bacterial disease development.
BSS/843/04	Control of pulmonary adenocarcinoma (jaagsiekte) in the Scottish sheep flock.
BSS/845/06	Epidemiology, population, health and infectious disease control.
BSS/035/06	Design of a sampling strategy for a survey to estimate the population density and distribution of badgers in Scotland.

External research contracts

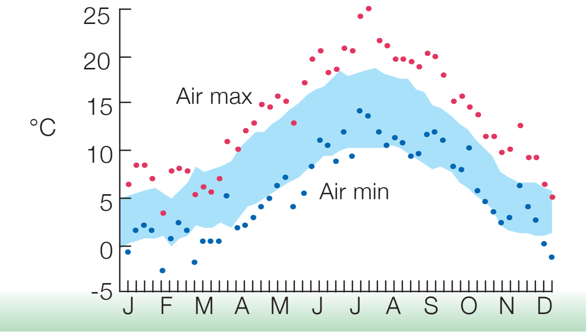
BBSRC	Visualisation and modelling of plant morphogenesis: a dynamic toolkit for cell expression and fluorescent cell reporters in roots.
BBSRC	Visualisation and analysis of biological sequences, alignments and structures.
BBSRC	Targeted induced mutation discovery in barley.
BBSRC LINK	Association genetics of UK elite barley.
BBSRC LINK	Role of inoculum sources in *Rhynchosporium* population dynamics and epidemics on barley.
BBSRC LINK	Testing trophic-functional relationships for modelling farmland diversity and functional dynamics.
BBSRC/University of Abertay	Plant root and microbial influence on soil water relations and structural stability.
British Council ARC Programme	A physically based understanding of crack genesis in soil and the impact of land management and biological processes.
British Potato Council	Developing effective integrated control measures for the control of black dot.
British Potato Council	Improving decision-making for the management of potato disease using real-time predictive diagnostics.
British Potato Council	Independent variety trials.
British Potato Council	Survey of GB blight populations.
British Potato Council	*Erwinia chrysanthemi* – the facts.
Carnegie Trust/British Ecological Society	New Zealand collaboration.
Commercial	Brassica breeding.
Commercial	Potato breeding.
Commercial	Molecular pathology.
Commercial	Blackcurrant breeding.
Commercial	Lipid analysis.
Commercial	Quality traits in fruit.
Commercial	Dormancy studies in potato.
Defra	Factors affecting cross-pollination in maize and oilseed rape crops growing under typical UK conditions.
Defra	Crop physiology.
Defra/HGCA	GREENGRAIN: Genetic reduction of energy use and emissions of nitrogen in cereal production (LINK).
Defra/SEERAD	Molecular breeding for root-rot resistant raspberries suitable for low input growing systems (HortLINK).
Defra/SEERAD	Integrated pest and disease management for high quality protected raspberry production.
EPSRC	Novel approaches to networks of interacting autonomes.
EPSRC/University of Dundee	A functional geotechnical study of how plant roots increase slope stability.
EU	ECOGEN: Soil ecological and economic evaluation of genetically modified crops.
EU	TREESNIPs: Developing single nucleotide polymorphism (SNP) markers for adaptive variation in forest trees.
EU	MABDE: Mapping adaptation of barley to drought environments.

EU	APOPHYS: Developing a physical and functional map of potato: creating new sources for molecular markers to breed cultivars with multiple resistance and quality traits.
EU	NOFORISK: Quantitative risk assessment strategies for novel foods.
EU	ALARM project.
EU	SIGMEA: Sustainable introduction of GM crops into European agriculture.
EU	SAFEFOODS: Promoting food safety through a new integrated risk analysis approach for foods.
EU	BIOEXPLOIT: Exploitation of natural plant biodiversity for the pesticide-free production of food.
EU	Improving seed quality in cereals by manipulating gene expression and partitioning.
EU	EURASNET: European alternative splicing network.
EU	EU-SOL: High quality solanaceous crops for consumers, processors and producers by exploration of natural biodiversity.
EU Marie Curie	Training site in plant virology.
EU Marie Curie	GENFUNDIV: Linking the genetic and functional diversity patterns of arbuscular mycorrhizal fungal communities in disturbed and undisturbed environments.
EU Marie Curie	Optimising the efficacy of phosphatase in the rhizosphere, increasing the sustainability of agricultural crops.
European Science Foundation	Exploiting genomics to understand plant–nematode interactions.
Food Standards Agency	Development of unified data models and data pre-processing strategies and the generation of meaningful, standardised statistical analyses of metabolome variability in crop plants.
HDC/SEERAD/Commercial	The breeding and commercial development of new raspberry varieties.
International Potato Center (CIP)	A saturated potato mutant population for functional genomics among Solanaceae and tuber crops.
MacRobert Trust	Biodiversity in Tayside.
Royal Society	Fundamental biophysical processes in the restoration of severely degraded soil by vegetation.
Royal Society	Involvement of the nucleolus in plant virus systemic infection.
Royal Society	Molecular basis of pathogenicity in the pine nematode *Bursaphelenchus xylophilus*.
Royal Society	Characterisation of plant genes that confer disease resistance to oomycetes.
Scottish Enterprise Tayside	Commercialisation award.
SEERAD Biodiversity Action Grants	The Living Field Study Centre.
SEERAD/BBSRC/GSK/HDC	Development of the physiological, agronomical and genetic tools for increasing L-ascorbic acid yield from blackcurrant bushes (HortLINK).
SEERAD/BPC/Commercial	Understanding and improving flavour characteristics of potato (LINK).
SEERAD/HDC	Developing a marker-assisted breeding toolkit for premium sensory characters in raspberries.
SHEFC	Scottish Bioinformatics Research Network (SBRN) maximising bioinformatics infrastructure for Scottish Health, Agriculture and Industry.

Meteorological Records 2006

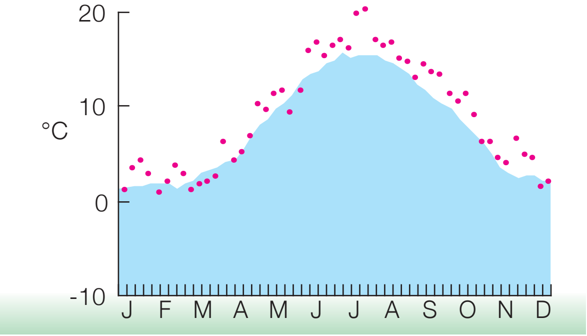
Marion Grassie

Temperature All months showed average maximum temperatures higher than the Long Term Average, except March which was the lowest for ten years. Most significant were June, July and September, all showing the highest temperatures on our records.

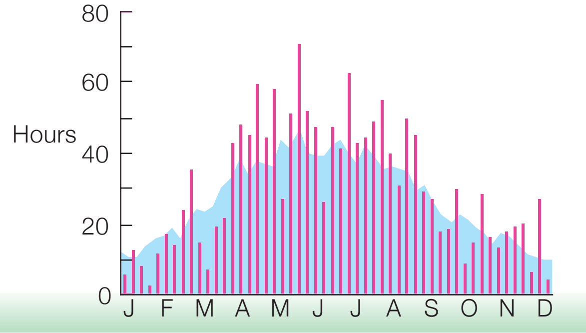

Air temperature

Average minimum temperatures were also higher than typical from June. Similarly, the number of days with frost was lower than the LTA from June, particularly October which had only one day's frost (LTA 10 days).

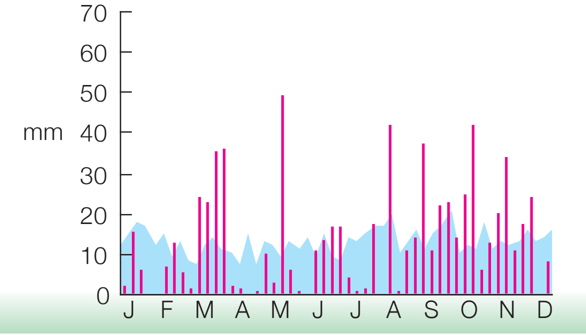
Mean soil temperatures were also higher than the LTA from June.


10cm soil temperature

Sunshine and solar radiation Sunshine figures were predominantly higher than normal from April which was notable. Solar radiation values were generally higher than normal, particularly April to July.


Sunshine

Rainfall Generally, rainfall was higher than normal. March had the highest value above the LTA and April was well below.


Rainfall

Wind On the whole, wind speeds were unexceptional. Exceptions were four recorded days of gale on 10th January and the 4th, 12th, 29th and 31st December, which also endured a thunderstorm with hail.


Run of wind

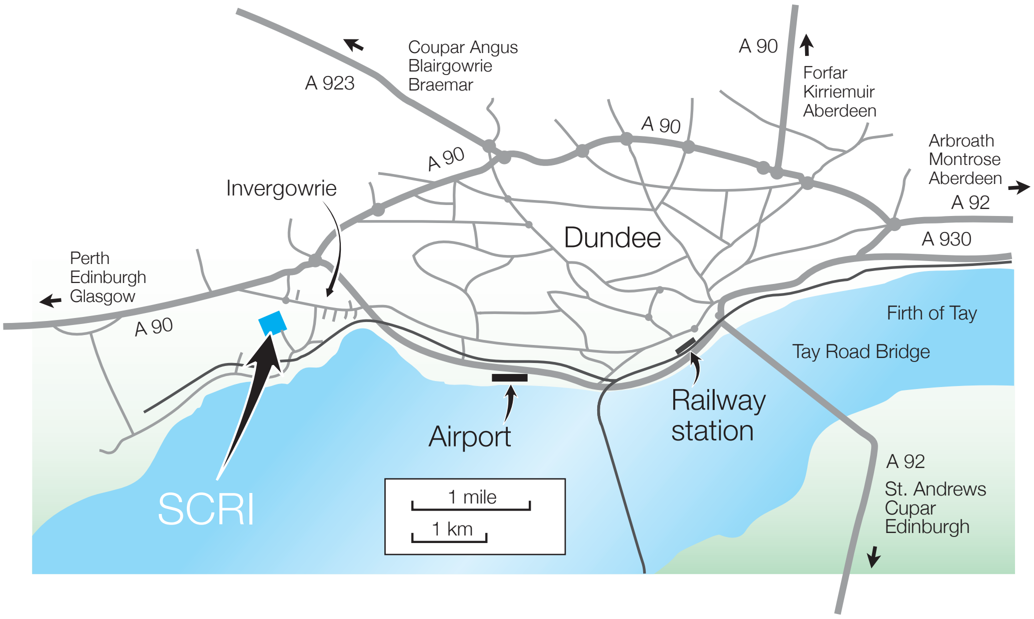
Institutes supported by the Biotechnology and Biological Sciences Research Council

BBSRC Office	Polaris House, North Star Avenue, Swindon, Wilts SN2 1UH	01793-413200
BBSRC Bioscience IT Services	West Common, Harpenden, Herts AL5 2JE	01582-714900
Babraham Institute	Babraham Research Campus, Cambridge CB2 4AT	01223-496000
Institute for Animal Health		
Compton Laboratory	Compton, Newbury, Berkshire RG20 7NN	01635-578411
Pirbright Laboratory	Ash Road, Pirbright, Surrey GU24 0NF	01483-232441
BBSRC & MRC Neuropathogenesis Unit	Ogston Building, West Mains Road, Edinburgh EH9 3JF	0131-667-5204
Rothamsted Research		
Rothamsted	Harpenden, Herts AL5 2JQ	01582-763133
Broom's Barn	Higham, Bury St. Edmunds, Suffolk IP28 6NP	01284-812200
Institute of Food Research	Norwich Research Park, Colney, Norwich NR4 7UA	01603-255000
Institute of Grassland and Environmental Research		
Aberystwyth Research Centre	Plas Gogerddan, Aberystwyth, Dyfed SY23 3EB	01970-823000
North Wyke Research Station	Okehampton, Devon EX20 2SB	01837-883500
Bronydd Mawr Research Station	Trecastle, Brecon, Powys LD3 8RD	01874-636480
Trawsgoed Research Farm	Trawsgoed, Aberystwyth, Dyfed SY23 4LL	01974-261615
John Innes Centre	Norwich Research Park, Colney, Norwich NR4 7UH	01603-450000
Roslin Institute	Roslin, Midlothian EH25 9PS	0131-527-4200
Silsoe Research Institute (Until March 2006)	Wrest Park, Silsoe, Bedford MK45 4HS	01525-860000

Scottish Agricultural and Biological Research Institutes

Hannah Research Institute (Until March 2006)	Ayr, Scotland KA6 5HL	01292-674000
The Macaulay Institute	Craigiebuckler, Aberdeen AB9 2QH	01224-498200
Moredun Research Institute	Pentlands Science Park, Bush Loan, Penicuik, Midlothian EH26 0PZ	0131-445-5111
Rowett Research Institute	Greenburn Road, Bucksburn, Aberdeen AB21 9SB	01224-712751
Scottish Crop Research Institute	Invergowrie, Dundee DD2 5DA	01382-562731
Biomathematics and Statistics Scotland (Administered by SCRI)	University of Edinburgh, James Clerk Maxwell Building, King's Buildings, Mayfield Road, Edinburgh EH9 3JZ	0131-650-4900

Access to SCRI



SCRI is on the east coast of Scotland, midway between Edinburgh and Aberdeen.

It is located at Invergowrie 6km west of the centre of Dundee. Access is via Riverside Avenue, Main Street and Errol Road.

British Rail has direct InterCity services between Dundee and London, Edinburgh and Glasgow and other UK cities.

Flights are available to Dundee Airport from London City, and scheduled services operate from many domestic and international destinations to Edinburgh and Glasgow.

scri

living technology