# SCOTTISH CROP RESEARCH INSTITUTE



# ANNUAL REPORT 1988

The Scottish Crop Research Institute, which is financed by the Department of Agriculture and Fisheries for Scotland and by commercial contracts, is part of the United Kingdom Agricultural and Food Research Service.

The objectives of the research programme are to advance knowledge in the biological sciences, to improve the quality of crops, and to improve the efficiency and predictability of crop production and crop protection systems, with due regard for the environment.


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£7.00 (post paid)

ISSN 0263-7200

Printed by
Milne, Tannahill & Methven Ltd., 113-119 Glover Street, Perth PH2 0JE

Published 1989

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# GENERAL REPORT

J. R. HILLMAN

In a year characterised by increasing public awareness of food standards and the quality of the environment, per capita world food production declined by 1.6%. Population growth, a sustained improvement in the economic performance of most nations, and a decrease in the area of cultivated land continued to place heavy demands on agricultural efficiency regardless of the vagaries of the weather. Research and development (R&D) activities in the non-medical life sciences were directed towards meeting social, political and economic expectations as well as fundamental scientific principles. Long-term economic projects and prospects of perturbations in the global climate served to emphasise the central role of biological research of the kind carried out in SCRI and other institutes in the Agricultural and Food Research Service (AFRS), and numerous disciplines were increasingly brought to bear on the major biological problems. Internationally, the age of the biologist was perceived by the scientific community to be well under way, with molecular biology occupying a high profile.

Within Europe, public and political opinions of the effects of the Common Agricultural Policy of the European Economic Community were focused for the most part on unwelcome changes to the countryside and expensive food surpluses/stockpiles. New policies were therefore formulated on subsidies, quotas, set-aside land, extensification, restrictions on pesticides and nitrogenous fertilizers, and reappraisals of R&D priorities. The relevant major research issues under active consideration at SCRI were pollution, reductions in xenobiotic inputs, implications of global warming with attendant climatic changes, production and release of genetically manipulated organisms, working gene-banks and germplasm collections, plant breeding, novel crops, crops for industrial processing, new pests and diseases, improvements in the efficiency of production of food and non-food agricultural commodities, soil processes, food quality, and relationships between agriculture and the natural flora and fauna. With 1992 in mind, there was intense activity in preparing proposals for coordinated national and international research programmes.

Profound changes were initiated in the funding and direction of agricultural and horticultural R&D in the UK public sector. Following a review of near-market R&D, the 'Barnes' Review, in organisations funded by the Department of Agriculture and Fisheries for Scotland (DAFS) and

the Ministry of Agriculture, Fisheries and Food (MAFF), a meeting was held in August involving civil servants, representatives of the agricultural industries, and senior staff from the Agricultural Development and Advisory Service of MAFF, the Agricultural and Food Research Council (AFRC), the Scottish Agricultural Colleges (SAC), and the Scottish Agricultural Research Institutes (SARIs). Various projects were identified as possible areas for transfer to industry funding. At the time, it was stressed that the lists of topics selected, their costings, the phasing of reductions in governmental funding and the very definition of 'near-market' were not fixed. The prospect of a precipitate withdrawal of funding during a time when SCRI was in the final stage of reorganising its research programmes and establishing new links with industry was both daunting and unsettling. However, Lord Sanderson of Bowden, Minister of State at the Scottish Office, addressed the Directors of the SARIs and the Principals of SAC at a meeting in November. He discussed SARI and SAC financing in the light of the Barnes Review, stressing seven main points, *viz.* (i) Government fully understands the basis of the anxiety and uncertainty in State-funded R&D organisations and has listened closely to the various views expressed; (ii) the need for R&D is accepted, and the science budget across all Government departments has been increased; (iii) value for money is a prerequisite; (iv) past achievements and the quality of the research base in Scotland is recognised; (v) there will have to be a transfer of funding of near-market R&D to the private sector which benefits directly from that work and in so doing give rise to much closer cooperation between R&D bodies and industry — State funds are for the support of fundamental and strategic research; (vi) the transition period would be difficult for all involved and allowance for this would be made; (vii) work in areas of the public interest and the environment would continue to receive support.

The outcome of the meeting and the subsequent Joint Management Board meeting with DAFS was that the provisional SCRI budget for the financial year 1989-1990 would be more or less the same as that in 1988 so wage and overhead cost increases would have to be absorbed. Preparation of a new DAFS strategy document of agricultural R&D will take place before projections can be given of SAC and institute funding post-1990.

During the year, a working group was set up to advise Ministers and the Chairman of the AFRC on the rationalisation of facilities for horticultural R&D in England, Wales and Scotland. Mr E. J. G. Smith, Deputy Secretary of MAFF and member of Council of AFRC chaired a group comprising representatives of AFRC, DAFS, MAFF, the Department of Education and Science (DES), and the chairman of the Horticultural Development Council and the Apple and Pear Development Council. SCRI submitted papers to the Committee and two Governing Body members, Mr J. A. Inverarity and Professor D. Boulter, attended one of the meetings. Horticultural research in the AFRC- and DAFS-funded

organisations has been extensively rationalised in recent years, but is nonetheless regarded as an area of work with a substantial near-market component. At SCRI, horticulturally related science is intimately linked with other areas of strategic work, and the Institute is recognised as an international centre of excellence and achievement in specific areas of the biology of soft fruit and ornamental species. There are important questions to be addressed about the management in times of severe budgetary constraint of various areas of agricultural and horticultural R&D. It is clear that the loss of expertise in some established, conventional areas of botanical science is becoming a noteworthy constraint. Of more concern is the extent to which scientific advances now depend on the input of a vast array of biological, physical, chemical and mathematical disciplines by committed individuals. This has implications in the interactions between institutes and universities, as well as the involvement of growers, grower organisations, food processors, retailers and chemical/pharmaceutical companies in setting objectives and funding near-market work. Enactment of the recommendations of the Smith working group may well provide a test-bed for gauging the success of integrating private industry with research in the public domain.

Enhanced coordination of the activities of ADAS, AFRC, SAC and SARIs, particularly in respect of contracts, was evidenced by the operation of a concordat based on the SCRI/SAC/ASS-East Craigs concordat. In addition, four commodity quartets were established as sub-committees of the Strategic Quintet which oversees coordination between the R&D bodies. I chaired the Crop Production Quartet and attended meetings of the Strategic Quintet, and Professor Innes was a member of the Horticultural Quartet.

On Friday 8 July, Lord Sanderson formally opened the new laboratory and office block that now bears his name. The following day was the Institute Open Day and in all respects it was a success. Around 1,700 visitors inspected the work of SCRI. The many compliments received about the staff and facilities, in addition to the favourable publicity, made the event very worthwhile. I thank the staff for their effort and commitment. Two other major building projects (Mycology glasshouse and headerhouse extension and Potato Genetics crop handling building) were on schedule for completion in early 1989 and two new projects (Potato Genetics main glasshouse-headerhouse complex and laboratory block) were put in train for starting at the end of the financial year. Plans for withdrawing all staff from Pentlandfield by that time were also drawn up, in parallel with preparations for closing the Murrays Farm.

Mr N. D. Anderson, Secretary of SCRI and its Governing Body, featured in the New Year Honours list with the award of an OBE. His outstanding dedication to the effective administration of the Institute and his non-vocational involvement in charitable works are recognised throughout the AFRS. In August he retired after 23 years service and the Institute appointed Dr R. J. Killick, formerly Assistant to the Director, in his stead.

Professor W. D. P. Stewart, F.R.S., Boyd Baxter Professor of Biology in the University of Dundee and former member of the SCRI Governing Body, was appointed Secretary of the AFRC on 1 January 1988. For many years he was involved in the AFRS, not only as a member of our Governing Body but as a holder of substantial AFRC competitive research awards, Royal Society Assessor to the AFRC Council and past member of the AFRC Plants and Soils Research Grant Board. He soon established new direction for the AFRC in its links with universities, other research councils, DAFS, MAFF and DES. New areas of science were opened up with particular emphasis on forging internationally recognised centres of excellence.

The Institute depends upon the help and cooperation of others, either individuals or organisations, without whose assistance the work would be greatly handicapped. The assistance takes the form of DAFS core funding and the helpfulness of the DAFS staff, grants from government agencies, local authorities and commercial companies, contracts, donations, farmers who generously make their land available for experiments, scientists with other organisations working on collaborative ventures, and the Scottish Society for Crop Research. SCRI is most grateful to all these collaborators and very appreciative of the help that they give.

*Major External Sources of Income*

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|---|---|
| Horticultural Development Council | £33,700 |
| Overseas Development Administration | £64,407 |
| Home Grown Cereals Authority | £50,607 |
| Beechams Foods Ltd | £14,541 |
| Agricultural Genetics Co | £17,110 |
| International Potato Center | £11,417 |
| Potato Marketing Board | £31,806 |
| United Biscuits | £29,127 |
| EEC | £27,080 |
| British Technology Group | £2,814 |
| Royal Botanic Gardens, Kew | £8,311 |
| SASS Consultancies and miscellaneous income | £106,000 |

*Permanent Appointments and Internal Transfers*

| | | |
|---|---|---|
| G. Bengough | HSO | Physiology and Crop Production Department |
| I. Bradbury | SSO | SASS, Ayr |
| S. T. Buckland | UG7 | SASS, Aberdeen |
| M. Catley | HSO | Zoology Department |
| M. C. Coleman | HSO | Potato Genetics Department |
| G. Cowan | ASO | Virology Department |
| J. W. Crawford | SSO | Physiology and Crop Production Department |
| D. Davidson | EWII | Tissue Culture Department |

| | | |
|---|---|---|
| G. Dow | EWIV | Estate Division |
| N. Dow | ASO | Brassica Genetics Department to Cereal and Legume Genetics Department |
| N. Duncan | ASO | Tissue Culture Department |
| G. Dunlop | ASO | Physiology and Crop Production Department |
| I. Fleming | EWIV | Estate Division |
| B. P. Forster | SSO | Tissue Culture Department |
| P. A. Gill | HSO | Physiology and Crop Production Department to Estate Division |
| J. M. Gorrod | ASO | Data Processing Department |
| F. Gourlay | EWII | Mycology and Bacteriology Department |
| C. A. Hackett | HSO | SASS, Dundee |
| G. W. Horgan | SSO | SASS, Edinburgh |
| D. J. Johnston | SO | Mycology and Bacteriology Department |
| A. Kumar | HSO | Tissue Culture Department |
| A. D. Lorimer | EWII | Cereal and Legume Genetics Department |
| F. H. Low | ASO | Chemistry Department |
| J. Low | ASO | Virology Department |
| J. Lyon | EWII | Cereal and Legume Genetics Department to Tissue Culture Department |
| A. L. March | ASO | Virology Department to Tissue Culture Department |
| R. J. Marshall | EWII | Cereal and Legume Genetics Department |
| C. J. McKenzie | ASO | Physiology and Crop Production Department |
| S. Millam | HSO | Tissue Culture Department |
| E. W. Milne | SO | Zoology Department to Virology Department |
| A. E. Morrice | ASO | Chemistry Department |
| R. Neilson | SO | Physiology and Crop Production Department to Zoology Department |
| I. M. Nevison | SO | SASS, Aberdeen |
| G. Pugh | EWIV | Estate Division |
| G. Ramsay | SSO | Cereal and Legume Genetics Department |
| B. Reavy | SSO | Virology Department |
| T. Shepherd | HSO | Physiology and Crop Production Department |
| L. Torrance | UG7 | Virology Department |
| R. Waugh | HSO | Tissue Culture Department |
| J. F. Wilkie | EWII | Chemistry Department |
| I. A. Young | HSO | Physiology and Crop Production Department |

*Awards*

| | |
|---|---|
| O. Acosta | PhD., University of Dundee, 1988. |
| B. Alexander | SCOTVEC Ordinary National Certificate in Biology. |
| N. D. Anderson | O.B.E. |

| | |
|---|---|
| J. R. K. Bennett | NPTC Certificate of Competence. Safe use of pesticides and ground crop sprayer — boom type hydraulic nozzle. |
| J. T. Bennett | NPTC Certificate of Competence. Safe use of pesticides and hand-held applicators (knapsack). |
| A. Booth | Cereal Crop Inspector's Licence. |
| C. C. Carrie | NPTC Certificate of Competence. Safe use of pesticides and ground crop sprayer — boom type hydraulic nozzle. |
| S. R. Clark | Scottish HNC in Computer Data Processing. |
| C. R. Dalrymple | NPTC Certificate of Competence. Safe use of pesticides and ground crop sprayer — boom type hydraulic nozzle. |
| B. Fleming | NPTC Certificate of Competence. Safe use of pesticides and hand-held applicators (knapsack). |
| E. A. M. Gardner | NPTC Certificate of Competence. Safe use of pesticides and hand-held applicators (knapsack). |
| A. E. Grant | NPTC Certificate of Competence. Safe use of pesticides and hand-held applicators (knapsack). |
| J. G. Guthrie | NPTC Certificate of Competence. Safe use of pesticides and hand-held applicators (knapsack). |
| W. D. J. Jack | NPTC Certificate of Competence. Safe use of pesticides and ground crop sprayer — boom type hydraulic nozzle. |
| A. D. Lindsay | NPTC Certificate of Competence. Safe use of pesticides and hand-held applicators (knapsack). |
| L. V. Lopez-Llorca | Ph.D., University of Dundee, 1988. |
| L. A. McNicoll | NPTC Certificate of Competence. Safe use of pesticides and ground crop sprayer — boom type hydraulic nozzle. |
| A. W. Mills | NPTC Certificate of Competence. Safe use of pesticides and ground crop sprayer — boom type hydraulic nozzle. |
| A. Nicoll | NPTC Certificate of Competence. Safe use of pesticides and hand-held applicators (knapsack). |
| R. Ogg | NPTC Certificate of Competence. Safe use of pesticides and hand-held applicators (knapsack). |
| D. S. Petrie | NPTC Certificate of Competence. Safe use of pesticides and ground crop sprayer — boom type hydraulic nozzle. |
| G. G. Pollock | NPTC Certificate of Competence. Safe use of pesticides and ground crop sprayer — boom type hydraulic nozzle.<br>ATB Certificate of Craftsmanship, Scottish Association of Young Farmers' Clubs. Certificate of Proficiency: Comprehensive Machinery. |
| W. Powell | Honorary Lecturer, University of St. Andrews. |

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|---|---|
| D. G. Pugh | NPTC Certificate of Competence. Safe use of pesticides and ground crop sprayer — boom type hydraulic nozzle. |
| R. W. Reid | RHAS Certificate and Medal for long service. |
| B. D. Robertson | NPTC Certificate of Competence. Safe use of pesticides and hand-held applicators (knapsack). |
| D. K. L. Robertson | NPTC Certificate of Competence. Safe use of pesticides and hand-held applicators (knapsack). |
| D. R. Simpson | RHAS Certificate and Medal for long service. |
| J. Small | RHAS Certificate and Medal for long service. |
| R. D. Taylor | RHAS Certificate and Medal for long service. |
| P. D. Waister | Royal Caledonian Horticultural Society, Scottish Horticultural Medal. |
| R. N. Wilson | NPTC Certificate of Competence. Safe use of pesticides and ground crops sprayer — boom type hydraulic nozzle. |
| P. W. Yeaman | NPTC Certificate of Competence. Safe use of pesticides and hand-held applicators (knapsack). |

*Promotions*

| | | |
|---|---|---|
| H. Barker | UG7 | Virology Department |
| J. R. K. Bennett | EWII | Estate Division |
| J. T. Bennett | EWIII | Estate Division |
| E. M. Burnett | SO | Mycology and Bacteriology Department |
| M. F. B. Dale | SSO | Potato Genetics Department |
| C. R. Dalrymple | EWI | Estate Division |
| D. A. Elston | HSO | SASS, Edinburgh |
| E. A. M. Gardner | EWI | Estate Division |
| D. W. Griffiths | SSO | Chemistry Department |
| L. J. Hyman | HSO | Mycology and Bacteriology Department |
| R. Kidger | HSO | Data Processing Department |
| W. H. Macfarlane Smith | UG7 | Brassica Genetics Department |
| A. Nicoll | EWI | Estate Division |
| D. S. Petrie | P&GSD | Estate Division |
| D. L. K. Robertson | EWIII | Estate Division |
| D. Robinson | SSO | Physiology and Crop Production Department |

*Resignations*

| | |
|---|---|
| J. Brown | Potato Genetics Department |
| M. Brunton | Virology Department |
| A. Dolan | Mycology and Bacteriology Department |
| J. M. Gorrod | Physiology and Crop Production Department |
| R. J. Marshall | Cereal and Legume Genetics Department |

| | |
|---|---|
| F. M. McGill | Mycology and Bacteriology Department |
| M. Mitchell | Virology Department |
| P. T. Logie | Estate Division |
| D. L. Robinson | SASS Edinburgh |
| J. Wardell | Virology Department |
| G. Wetherill | SASS Edinburgh |
| C. J. Wilkinson | Physiology and Crop Production Department |
| W. Wood | SASS Edinburgh |

*Termination of Short-term Appointments*

| | |
|---|---|
| J. N. Burdon | Soft Fruit Genetics Department |
| A. Butler | Potato Genetics Department |
| A. Morrice | Brassica Genetics Department |
| A. V. Wheelwright | SASS Edinburgh |

*Retirements of Permanent Staff*

N. D. Anderson, UG7, Institute Secretary, retired on 31st August after 23 years service.

J. Small, P&GSE, Estate Division, retired on 16 March after 34 years' service.

P. D. Waister, UG6, retired as Head of Crop Sciences Division and Head of Physiology and Crop Production Department after 23 years' service.

*Visiting Workers*

R. Alonso (National Institute of Agricultural Research, Madrid, Spain) spent 3 months working on expert systems (SASS Edinburgh).

S. Anderson (Department of Mathematics, Royal Veterinary and Agricultural University, Copenhagen, Denmark) spent 2 weeks studying the analysis of ordinal data (SASS Edinburgh).

J. Aumann (Institute of Phytopathology, University of Kiel, West Germany) spent 2 weeks in November/December working on microinjection of nematode extracts into plants (Zoology Department).

I. Bahner (Department of Biochemistry and Microbiology, University of St. Andrews) spent several weeks in Virology Department assisting in the work of the Link Group at St. Andrews on the non-structural proteins of potato leafroll virus (Virology Department).

M. C. Carvalho (Ministry of Agriculture, Oporto, Portugal) visited for 2 weeks in December to learn techniques of handling *Erwinia* spp. (Mycology and Bacteriology Department).

C. Castro (University of North Wales, Bangor) discussed work on late blight of potatoes for 2 days (Mycology and Bacteriology Department).

M. Coiro and A. Agostinelli (University of Bari, Italy) spent 2 weeks in June studying the taxonomy of trichodorid nematodes (Zoology Department).

M. V. Cortes Rodriguez (National University of Colombia) spent 1 week from 15 September discussing the problems of soft fruit pathology (Mycology and Bacteriology Department).

D. Fargette (ORSTOM, Ivory Coast) arrived in January to spend 1 year studying viruses of cassava (Virology Department).

M. Fargette (ORSTOM, Ivory Coast) spent 1988 undertaking a biochemical and molecular analysis of populations of *Meloidogyne* which differ in their virulence on resistant cultivars (Zoology Department).

C. Fasseus (Agricultural College of Athens, Greece) arrived in March to spend a sabbatical year studying ultrastructural aspects of parsnip yellow fleck virus infection and transmission (Virology Division).

Deborah Gould (University of St Andrews) spent 4 months on transformation and mutation of *Phytophthora infestans* (Mycology and Bacteriology Department).

N. Heiberg (Njos Research Station, Norway) visited for 1 week commencing 11 August to acquire specialist knowledge on raspberry root rot (Mycology and Bacteriology Department).

B. Johnson (Michigan State University, East Lansing, Michigan, USA) spent 1 week in August comparing SCRI and Ceres models of potato growth using SCRI data (Physiology and Crop Production Department).

J. Landeo (CIP, Peru) discussed work on late blight of potatoes for 2 days (Mycology and Bacteriology Department).

P. N'Guessan (ORSTOM, Ivory Coast) arrived in September to spend 1 year learning techniques for studying geminiviruses affecting tropical crops (Virology Department).

Z.-Y. Peng (Chinese Academy of Agricultural Sciences) arrived to work for 2 years on drought tolerance in potato (Physiology and Crop Production Department).

T. Ploeg (Laboratory for Nematology, Agricultural University, Wageningen, The Netherlands) spent 9 months researching specificity of Trichodorid nematodes as vectors of strains of tobacco rattle virus (Zoology Department).

S. Pluta (Institute of Pomology and Floriculture, Skierniewice, Poland) spent 10 months studying the breeding of black currants, funded by the British Council (Soft Fruit Genetics Department).

J. da Silva (Copersucar, Brazil) spent 4 weeks training in trial design and Genstat 5. (SASS Edinburgh).

S. L. Soria (National Institute of Agriculture Research, Madrid, Spain) spent 3 weeks continuing collaborative work on synthetic aperture radar data from satellites (SASS Edinburgh).

J. M. Stewart (University of Manitoba, Canada) discussed collaborative programmes on microbiology of peat between 16-25 February (Mycology and Bacteriology Department).

L. Turkensteen (IPO, The Netherlands) and J. A. Landeo (CIP, Peru) visited for 1 week from 14 April examining techniques of culturing and production of protoplasts of *Phytophthora infestans* (Mycology and Bacteriology Department).

X.-F. Wang (Academia Sinica, Beijing, China) arrived in August on a Royal Society exchange visit to spend 5 months studying molecular aspects of geminiviruses (Virology Department).

H. F. Zhou (Shenyang Agricultural University, China) arrived in November for 1 year to study the application of statistical methods in agricultural research (SASS Edinburgh).

L. Zoadelli (University of Milan, Italy) came to work for 1 month on low temperature sweetening of potato tubers (Physiology and Crop Production Department).

*Research Students*

O. Acosta (Post-graduate student from Colombia — funded by Society for General Microbiology) completed his studies on the replication of raspberry ringspot virus in *Nicotiana* protoplasts (Virology Department).

K. Backett (SERC-CASE with University of Leeds), began developing a rapid means of identifying resistance to potato cyst nematodes based on the use of antibodies (Zoology Department).

R. Bargota (AFRC-CASE with University of London) commenced studies on starch biosynthesis in developing Vicia seed (Physiology and Crop Production Department).

U. Brown (SERC-CASE with University of Glasgow) commenced studies on gene activation during potato starch mobilisation (Physiology and Crop Production Department).

K. Chalmers (SERC with University of St. Andrews). Studies of molecular genetics of barley (Tissue Culture).

Mrs Sumeda Dharmaratne from Rubber Research Institute, Sri Lanka, funded by World Bank, continued to investigate self-incompatibility in *Brassica napus* (Brassica Genetics Department).

S. J. Finnie (SERC with University of Edinburgh). Haploid production in barley (Tissue Culture Department).

S. Friar (LCA Wolverhampton Polytechnic). Transformation methods in *Brassica napus* (Tissue Culture Department).

A. Gleadle (PMB, University of Nottingham). Somatic hybridisation in potato (Tissue Culture Department).

J. A. Gonzales-Perez (Post-graduate student from the Canary Islands) started research on the biochemical and molecular identification of introductions of potato cyst nematodes (Zoology Department).

L. V. Lopez-Llorca (Post-graduate student funded by the British Council) completed his studies on the role of nematophagous fungi in the natural control of cyst nematodes (Zoology Department).

L. A. MacCulloch (DAFS post-graduate student, University of Aberdeen) continued research on chemo- and electrotactic localisation of roots by pathogens (Zoology Department).

C. MacNaughton-Smith (SERC-CASE with University of Edinburgh) continued studies on sucrose-starch conversion in developing potato tubers (Physiology and Crop Production Department).

R. Moon (SERC-RCCA with University of St. Andrews) continued studies on gene transformation systems in *Phytophthora infestans* (Mycology and Bacteriology Department).

Z.-Y. Peng (CIP funded) commenced a study of the physiological basis of drought tolerance in potato (Physiology and Crop Production Department).

J. Phelpstead (SERC-CASE, with University of Nottingham). Studies of cell biology of potato (Tissue Culture Department).

A. T. Ploeg (Post-graduate student partly funded by the British Council) started research on the specificity of Trichodorid species as vectors of tobacco rattle virus (Zoology Department).

P. Purcell (SERC with University of Edinburgh). Studies of mitochondrial biogenesis in potato (Tissue Culture Department).

L. D. Ramsay (SERC-RCCA with University of Birmingham) continued studies on applications of biometrical genetics to swede breeding (Brassica Genetics Department).

M. Roberts (SERC-CASE with University of Leicester). Transposon mutagenesis in flax (Tissue Culture Department).

K. P. Scott (Post-graduate student funded by DAFS) began research on the genome structure of potato mop-top virus (Virology Department).

J. C. Seraphin (Coiana Enterprise for Agricultural and Cattle Raising Research, Brazil, post-graduate student with University of Edinburgh) began studies on cultivar trials and variance components (SASS Edinburgh).

J. M. Smith (SERC-RCCA with University of London) commenced studies on DNA polymorphisms as genetic markers for rust fungi (Mycology and Bacteriology Department).

Natalie T. Smoktunowicz (PMB funded) continued a 2 year study on the influence of nitrogen on carbon partitioning in potato (Physiology and Crop Production Department).

I. Toth (SERC-RCCA with University of Warwick) continued studies on genetic analysis of pathogenicity of *Erwinia carotovora* (Mycology and Bacteriology Department).

R. Viola (Post-graduate student funded by EEC) commenced studies on carbohydrate metabolism in potato (Physiology and Crop Production Department).

W. Wallis (MAFF post-graduate student, jointly with University College of North Wales, Bangor) began studies on the biology and detection of *Rubus* downy mildew (Mycology and Bacteriology Department).

A. Ward (SERC-CASE with University of Nottingham). Application of protoplast technology in potato improvement (Tissue Culture Department).

W. van der Wen (AFRC) Construction of a genetic linkage map in *Vicia faba* (Tissue Culture Department).

S. Wharam (SERC-RCCA with University of Warwick) commenced studies on molecular genetics of erwinia pathogenicity (Mycology and Bacteriology Department).

Alison V. Wheelwright (SERC with University of Edinburgh) began studies on estimating edges in medical images (SASS Edinburgh).

*Short-Term Appointments*

M. M. Aiton and P. F. McGrath (ODA funded). Four year study on characterisation and diagnosis of whitefly-transmitted viruses (Virology Department).

J. Bruce (BTG funding), one year for separation and screening of compounds for nematicidal activity (Zoology with Chemistry and Mycology and Bacteriology Departments).

J. N. Burdon (HDC/Beechams funded) for 3 months to study the role of ethylene in the abscission of black currant flowers (Soft Fruit Genetics Department).

J. P. Camm (HGCA) for 3 year study of milling energy and barley malting quality (Cereal & Legume Genetics Department).

D. Cawston (DAFS) Genetical studies of microspore derived lines of barley (Tissue Culture Department).

Mrs I. Christie (DANI funded) updated the Herbrex data base (Physiology and Crop Production Department).

M. Coleman (United Biscuits) Limited Genome transfer in potato (Tissue Culture Department).

E. Cuthbert (PMB funded) commenced a 1 year study of physiological markers for maturity in potatoes. (Physiology and Crop Production Department).

P. Davie (United Biscuits) Limited genome transfer in potato (Tissue Culture Department).

P. M. Derrick (IFS) for 3 year study on the influence of virus infection on intercellular transport via plasmodesmata. (Virology and Physiology and Crop Production departments).

M-J. Farmer (IFS) for 3 year study on monoclonal antibodies to potato viruses (Virology Department).

R. Forrest (IFS) for 3 year study of potato cell wall components as elicitors of plant resistance mechanisms (Mycology and Bacteriology Department).

D. Hedley and G. MacMillan (PMB) for 3 year study of the biochemistry of preformed resistance to erwinias in potatoes (Mycology and Bacteriology Department).

T. D. Heilbronn (PMB funded) continued a project on forecasting the yield of the national potato crop from weather and soil data and agronomic practice (Physiology and Crop Production Department).

D. S. Kidd (IFS) for 3 year to study use of *Agrobacterium* species as vectors of DNA (Soft Fruit Genetics Department).

I. K. Kumar (ODA funded) for 3 year study of virus components involved in groundnut rosette disease (Virology Department).

S. Kumar (IFS) Somatic hybridisation of potato (Tissue Culture Department).

P. Lanham and K. McIlravey (IFS) for 3 year study of the molecular genetics of regulation of pectic enzyme production in erwinias (Mycology and Bacteriology Department).

J. Lyon (IFS) Transposon mutagenesis in potato (Tissue Culture Department).

G. MacDonald for 6 months to study support of potato genetics research at Pentlandfield (Potato Genetics Department).

Wendy J. McGavin (funded by Royal Botanic Gardens, Kew) for 1 year to study pesticidal potential of natural plant products (Zoology Department).

S. McIntosh (HGCA funded) continued a 3 year study on the effects of weed control strategies in cereals on the weed seed bank of arable soils (Physiology and Crop Production Department).

Angela Monaghan (HDC funded) completed a 9 month assignment to assist with the evaluation of alternative method of cane vigour control in raspberries (Physiology and Crop Production Department).

E. A. Murant (AGC funded) for 3 year study of genetic engineering of virus resistance (Virology Department).

M. Ramsay (IFS) for *in vitro* selection in *Brassica* spp. (Brassica Genetics Department).

F. Ritchie for 6 months to study management of working quality assessment of potato clones and research into processing quality (Potato Genetics Department).

P. H. Scott (HDC) for 3 year study of *Phytophthora* root rot of raspberries (Mycology and Bacteriology Department).

A. J. Soutar, 1 year from November, working with the Coordinated Variety Trials section (SASS Edinburgh).

L. S. Talbot (IFS) continued studies on calcium-related disorders of potato tubers (Physiology and Crop Production Department).

D. Todd for 6 months to study maintenance of diploid potato museum and general research support (Potato Genetics Department).

J. Wardell (IFS) for 3 year study of the genome structure of raspberry ringspot virus (Virology Department).

C. Watkins (DAFS) for 3 year study of the etiology of strawberry June yellows (Virology Department).

P. Whitty (IFS) Transposon mutagenesis in potato (Tissue Culture Department).

K. M. Wright (IFS) continued study of control of sucrose partitioning in source versus sink potato tuber tissue (Physiology and Crop Production Department).

*Sandwich Course Students*

A. Cassidy (Dundee Institute of Technology) for 3 months preparing lines for genetical studies of starch variants in barley (Cereal & Legume Genetics Department).

P. Engelmeers (Agricultural University, Wageningen, The Netherlands) for 5 months working on aspects of the 'running-off' disorder of black currants (Soft Fruit Genetics Department).

Lisa Fyffe (Dundee Institute of Technology) spent 3 months working on race determination of isolates of *Phytophthora infestans* (Mycology and Bacteriology Department).

L. Gregory (Dundee College of Technology) assisted with laboratory and field experiments (Physiology and Crop Production Department).

M. D. Harrington (North East London Polytechnic) worked on mechanisms of resistance in raspberry to aphids (Zoology and Virology departments).

E. Ivens (Agricultural University, Wageningen, The Netherlands) spent 3 months examining factors influencing the efficiency of extraction of weed seeds from soil samples (Physiology and Crop Production Department).

Jose Kok (Agricultural University, Wageningen, The Netherlands) for 3 months working on anther culture and competition in spring barley (Cereal & Legume Genetics Department).

M. Macaulay (Dundee Institute of Technology) worked for 6 months on the autofluorescent response of barley to mildew infection (Mycology and Bacteriology Department).

Mary Mitchell (Dundee College of Technology) developed a growth-stage data-base for weed susceptibility to herbicides for use in Herbrex (Physiology and Crop Production Department).

H. Fiona O'Brien (Coventry Polytechnic) assisted scientific staff at the Macaulay Land Use Research Institute, Aberdeen (SASS Aberdeen).

T. Orsman (North East London Polytechnic) for 12 months research into dihaploids and germplasm enhancement in potatoes (Potato Genetics Department).

S. A. Rodger (Dundee College of Technology) assisted studies on virus-vector and non-vector strains of *Olpidium brassicae* (Zoology and Virology Departments).

Deborah Smith (Dundee Institute of Technology) worked for 6 months on the production of monoclonal antibodies to pectate lyase from erwinias (Mycology and Bacteriology Department).

P. Tam (University of Bath) assisted with coordinated variety trials. (SASS Edinburgh).

Ann Todd (Dundee College of Technology) worked as meteorological observer and assisted with work on drought tolerance in potato (Physiology and Crop Production Department).

Jennifer Watters (Dundee Institute of Technology) spent 5 months working on extracellular enzymes of *Botrytis cinerea* (Mycology and Bacteriology Department).

*Visits Abroad*

M. M. Aiton visited the University of Agricultural Sciences, Bangalore and the Indian Agricultural Research Institute, New Delhi on 9-30 November to undertake research, funded by ODA, on detection and variation among isolates of whitefly-transmitted geminiviruses.

B. Boag and D. J. F. Brown visited the Agricultural University, Uppsala, Sweden from 5-9 May to discuss collaboration on the pine wilt and virus vector nematodes and advise on the programme for the meeting of the European Society of Nematology. From 6-12 June they also attended a NATO sponsored workshop on the use of computers in taxonomy at Raleigh, N. Carolina, USA.

B. Boag, D. J. F. Brown and D. L. Trudgill participated in a British Council sponsored weekend workshop in Alnarp, Sweden from 29-31 October to discuss soil-borne viruses of potato.

R. M. Brennan visited the Institute of Horticulture, Piikkio, Finland, and the Division of Fruit Breeding, Balsgard, Sweden, from 1-8 August for discussions with small fruit breeders and assessment of germplasm and to attend a meeting of the Nordic Gene Bank (funded by the Beecham Bovril Brands Research Fund).

D. J. F. Brown and A. T. Ploeg visited the Agricultural University, Wageningen, Leiden University, and the Flower Bulb Research Institute, The Netherlands from 15-20 May to discuss research related to transmission of tobraviruses by Trichodorid nematodes.

S. T. Buckland visited USA, 25 April-10 June, to attend the annual conference of the International Whaling Commission as consultant on assessing Minke Whale populations.

M. R. Cormack visited The Netherlands to study a novel growing system for raspberries, 9-13 February. At the invitation of the University of Chile, he visited Santiago to present lectures and have discussions on raspberry growing, 17 June-4 July.

M. F. B. Dale visited Cyprus 14-18 May and N. Spain 8-12 October to assess SCRI potatoes in trials. He also visited Sweden 7-13 August to attend a nematology conference.

H. V. Davies visited the Max-Planck Institute, Köln, 12-14 April and INRA, Dijon, 14-15 April, to arrange collaborative research programmes funded by EEC. He also visited the University of Milan, 16-18 May, and the Institute for Tropical Agriculture, Florence, 19-20 May, to present seminars and met with representatives of the European Chip and Snack Association in Amsterdam to discuss funding, 17-18 October.

C. A. Glasbey visited Montpellier, France, 18-21 September as an invited participant at the Anglo-French Data Analysis workshop. He visited Madrid, Spain, 5-12 June, to initiate collaboration on the analysis of synthetic aperture radar data from satellites with the Remote Sensing Group of the National Institute of Agricultural Research, as part of a scientific exchange programme funded by the British Council and Spanish Ministry of Education.

S. C. Gordon visited the major *Rubus* growing areas of British Columbia (Canada) and Oregon and Washington State (USA) from 10-21 July as part of a study tour examining entomological problems associated with the crop and with machine harvesting.

D. W. Griffiths visited Wageningen, The Netherlands, 23-25 November to attend and to act as moderator for tannin and alkaloid sessions of a Workshop on Antinutritional Factors in Legume Seeds.

B. D. Harrison made an invited visit to Mogen International and the University of Leiden, The Netherlands on 7-8 April to lecture and to discuss genetic engineering of virus resistance. On 25-27 April he attended a meeting in Paris to plan research on engineered virus resistance of cassava, by invitation of ORSTOM. From 14 May-5 June he visited institutes and universities in China under the Royal Society-Academia Sinica exchange scheme to give lectures and discuss plant virus research. On 16-19 August he and A. F. Murant made invited visits to centres of plant virus research in Hokkaido, Japan for discussions and to give seminars.

J. R. Hillman attended the Flax Workshop, Brussels, 4-5 May to discuss research priorities in a meeting organised by the Directorate-General for Agriculture VI, Commission of the European Communities.

G. W. Horgan visited Praia, Cape Verde, 24 August-9 September, on an EC-funded mission to assist the Agricultural Statistics Department of the Ministry for Rural Development with the setting up of software to analyse the results of agricultural censuses and surveys.

N. L. Innes attended Governing Board Meetings of the ICRISAT in Hyderabad, India, from 24-30 March and of the CIP in Lima, Peru, from 2-9 December. He also attended the EUCARPIA International Congress on Genetic Manipulation in Plant Breeding at Elsinore, Denmark, 11-16 September.

D. L. Jennings visited Fundocion Chile, Santiago, Chile, from 12-14 July to lecture on *Rubus* cultivars and culture.

A. T. Jones visited the Fruit Breeding Division of the Swedish University of Sciences at Balsgard and Alnarp on 14-18 May to discuss virus indexing of *Ribes* germplasm. The visit was funded by Beechams Foods.

R. A. Kempton visited Dublin, 2-4 May, where he gave a seminar at Trinity College and visited the National Food Centre of the Agricultural Institute.

G. R. Mackay visited Valencia, Spain, in July to collect data from potato trials.

G. R. Mackay & R. L. Wastie visited Gilat Experimental Station, Israel, 16-24 May to assess SCRI potato clones in trials and to discuss research into *Alternaria* and *Verticillium* resistance.

D. K. L. MacKerron visited Brussels, Belgium to attend a meeting of EC joint Faba bean trials (Northern) group on 17-18 November to finalise arrangements for a new round of trials linked to studies of animal nutrition and of plant physiology.

J. W. McNicol, together with I. A. Cowe of the Chemistry Department, visited Maryland, USA, 28-29 September, to discuss the sale of their software package, Principal Components Analysis of Near Infra Red spectra, to Pacific Scientific Company.

B. Marshall was invited on a research fellowship to work with Dr Ir J. Vos and Prof P. Struik in the Department of Field Crops and Grassland Research, University of Wageningen, The Netherlands, for a period of 3 months. July-October, on aspects of photosynthesis, nutrition and tuber size distribution in potato.

D. T. Mason visited various EEC offices in Brussels, Belgium, 20-22 April, to investigate sources of funding for work at SCRI.

M. A. Mayo attended the Fifth International Congress of Plant Pathology, Kyoto from 20-27 August, and the joint meeting of the Sektion Virologie der Deutschen Gesellschaft für Hygiene und Mikrobiologie and the Society for General Microbiology, Hamburg from 15-17 September. He visited workers at Institut de Biologie Moleculaire des Plantes, Strasbourg on 20-21 September for discussions on collaborative work and he also visited the University of Würzburg on 5-6 December to give an invited seminar and discuss aspects of molecular plant virology.

W. P. Mowat visited the Bulb Research Centre and the Bulb Inspection Service at Lisse, The Netherlands, and Dutch bulb farms in the vicinity, during 26-28 April to discuss viruses affecting flower bulbs and new developments in the bulb industry.

K. J. Oparka made an invited visit to the Plant Transport Group, University of Utrecht, The Netherlands, from 3-12 October to discuss joint research interests and delivered a seminar on sucrose transport in storage tissues.

M. C. M. Pérombelon visited Victoria and New South Wales, Australia on 2-25 March to advise Potato Growers Associations on control of potato blackleg. He visited agricultural research establishments in China on 28 August-3 September, under the auspices of the Chinese Association, for Science and Technology.

W. Powell visited Wageningen, The Netherlands from 23-24 April to attend the Editorial Board Meeting of Potato Research. He visited the Max-Planck Institute, Cologne on 25 April to discuss RFLPs in potato genetics.

B. Reavy attended the 2nd International Congress of Plant Molecular Biology held at Jerusalem, Israel on 13-18 November.

I. M. Roberts visited ICRISAT, Hyderabad, India, from 17-30 January as consultant in electron microscopy. From 30 January-6 February he visited the University of Agricultural Sciences, Bangalore and IARI, New Delhi for discussions on electron microscopy of plant viruses.

D. J. Robinson visited the Biologische Bundesanstalt, Braunschweig, West Germany on 11-14 April to take part in a COST-88 Workshop on detection of plant pathogens by complementary nucleic acid probes.

M. Talbot visited Poland, 31 May-3 June, as an invited speaker at a workshop on statistical methods at the Polish Variety Testing Centre; visited Namur, Belgium, 18-22 July, as an invited session organiser at the XIVth International Biometric Conference; and visited Madrid, Spain, 3-7 October, as an invited participant at a meeting organised by the Spanish Agricultural Development and Advisory Service.

D. L. Trudgill attended EPPO sponsored *ad hoc* meetings on pine wood and potato cyst nematodes in Uppsala, Sweden and Paris, France on 9-10 February and 28-29 September respectively.

*Conferences at which papers were given*
(Names in parenthesis are joint authors)

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| 17-18 February | Royal Society Discussion Meeting, London | |
| | B. D. Harrison<br>(D. J. Robinson) | Molecular variation in vector-borne plant viruses: epidemiological significance. |
| 23-26 February | Conference of the Cereal Section of EUCARPIA, Wageningen, The Netherlands | |
| | J. S. Swanston<br>(W. T. B. Thomas)<br>(M. J. C. Asher[1])<br>(C. E. Thomas) | The transfer of resistance to powdery mildew from *Hordeum spontaneum* to the spring barley cv. Golden Promise. |
| 24 February | SSPDC Potato Parliament, Dundee | |
| | J. R. Hillman | Research and development. |
| 24 February | West of England Fruit Conference, Worcester | |
| | J. M. Duncan | *Phytophthora* species attacking strawberries and raspberries. |
| 25 February | Walkers Potatoes-Potato Conference | |
| | D. K. L. MacKerron | Irrigation and tuber quality for crisps. |
| 9 March | Overseas Development Natural Resources Institute London | |
| | J. R. Hillman | R&D capability of SCRI. |
| 15 March | Horticultural Development Council Soft Fruit Seminar, Stockbridge House EHS, Selby | |
| | H. M. Lawson<br>(M. R. Cormack)<br>(R. M. Brennan) | Progress report on HDC funded projects on novel fruit crops and raspberry cane management at SCRI. |
| | J. M. Duncan<br>(D. M. Kennedy) | Root rot of raspberry |

[1]IACR Brooms Barn Experiment Station

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| 29-30 March | Chemometrics Group, Royal Society of Chemistry, Edinburgh | |
| | J. W. McNicol<br>(I. A. Cowe)<br>(D. C. Cuthbertson) | Principal Component Analysis of Near Infra Red Spectra. |
| 4-9 April | El Suelo en la Patologia Vegetal, Toledo, Spain | |
| | D. L. Trudgill<br>(W. M. Robertson)<br>(B. Boag)<br>(L. V. Lopez-Llorca)<br>(B. R. Kerry[1]) | Control biologico de nematodos fitoparasitos con especial referencia al nematodo de los cereales, *Heterodera avenae* |
| 10-14 April | Society for General Microbiology, Warwick | |
| | M. A. Mayo<br>(O. Acosta) | Anomalous behaviour by raspberry ringspot virus coat protein. |
| | M-J. Farmer<br>(B. D. Harrison) | Analysis of epitopes of potyvirus particle protein |
| 12 April | Horticultural Development Council Growers Meeting, Long Ashton, Bristol | |
| | D. M. Kennedy | Root rot of raspberry. |
| 12-15 April | 208th Meeting of the Genetical Society, Norwich | |
| | T. Hodgkin<br>(D. Gemmell)<br>(S. Dharmaratne)<br>(J. E. Bradshaw) | Self-incompatibility in *Brassica napus:* A two locus sporophytic system. |
| 15 April | Environmental Health Conference, University of Dundee | |
| | D. K. L. MacKerron | Radiation in the environment: The biological perspective. |
| 28 April | Netherlands Circle of Plant Virology, Wageningen, The Netherlands | |
| | W. P. Mowat | Identification of narcissus yellow stripe potyvirus with an antiserum to a non-structural virus protein. |
| 4 May | Scottish Mycology and Plant Pathology Club, Edinburgh | |
| | B. Williamson | Spot anthracnoses caused by *Elsinoe* and *Sphaceloma.* |

[1]IACR Rothamsted Experimental Station

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| 10 May | Association of Applied Biologists. Implications of genotype and environment interaction, Cambridge. | |
| | M. F. B. Dale<br>(M. S. Phillips) | G X E interactions in the assessment of potato cyst nematode tolerance in potato yield trials. |
| 22-27 May | International Strawberry Symposium, Cesena, Italy | |
| | D. L. Jennings | The use of multivariate analyses for study of autumn-fruiting strawberries. |
| 23-27 May | NATO Advanced Research Workshop, Greece | |
| | M. C. M. Pérombelon<br>(L. J. Hyman) | Sources and pathways of contamination of potatoes by soft rot erwinias in Scotland. |
| | M. C. M. Pérombelon<br>(E. M. Burnett)<br>(S. Melvin)<br>(S. Black) | Preliminary studies on the control of potato blackleg by hot water treatment of seed tubers. |
| | M. C. M. Pérombelon<br>(V. M. Lumb)<br>(D. Zutra)<br>(L. J. Hyman)<br>(E. M. Burnett) | Factors affecting potato blackleg development. |
| 25 May | Scottish Plant Physiology Group, Stirling University | |
| | H. V. Davies | Biochemical regulation of low temperature sweetening in potatoes. |
| | K. J. Oparka | Turgor-regulated sucrose partitioning. |
| 30 May-2 June | 7th International Symposium on Virus Diseases of Ornamental Plants, San Remo, Italy | |
| | W. P. Mowat<br>(G. H. Duncan)<br>(S. Dawson) | An appraisal of the identities of potyviruses infecting narcissus. |
| 30 May-3 June | European Association for Potato Research, Physiology Section, Jerusalem, Israel | |
| | D. K. L. MacKerron | Proposals for an integrated and coordinated study of drought tolerance in potato. |
| 30 May-4 June | 10th International Symposium on Sexual Reproduction in Higher Plants, Siena, Italy | |
| | J. R. T. Hodgkin | In vitro pollen selection in *Brassica napus* |

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| 6-10 June | NATO Advanced Research Workshop on the Morphological Identification of Plant-Parasitic Nematoda Genera, Raleigh, USA | |
| | B. Boag<br>(P. B. Topham)<br>(D. J. F. Brown)<br>(P. Smith) | The use of microcomputers for the identification of plant parasitic nematodes. |
| | D. J. F. Brown<br>(B. Boag) | Morphological variability and aberrations in nematode identification. |
| 10 June | Scottish Diagnostic Virology Group, Dundee | |
| | M. M. Aiton<br>(P. M. McGrath)<br>(B. D. Harrison) | Three groups of geminivirus isolates from cassava distinguished by reactions with monoclonal antibodies. |
| | M-J. Farmer<br>(B. D. Harrison) | Analysis of epitopes of potyvirus particle proteins. |
| 12-16 June | 27th Annual Meeting of the American Society of Nematologists, Raleigh, USA | |
| | B. Boag<br>(W. M. Robertson) | The specificity of nematophagous fungi for plant parasitic nematodes. |
| | D. J. F. Brown | Standardisation of requirements by nematological journals for taxonomic descriptions including deposition of specimens in internationally agreed collections. |
| | D. J. F. Brown<br>(A. T. Ploeg)<br>(D. J. Robinson) | Preliminary studies on the transmission of tobacco rattle virus by trichodorid nematodes. |
| | D. J. F. Brown<br>(D. L. Trudgill)<br>(A. F. Murant) | Serological variability in nepoviruses and its effects on specificity of transmission by nematodes. |
| | J. M. S. Forrest<br>(E. W. Milne)<br>(W. M. Robertson) | Studies on the nature of the cuticle surface of the potato cyst nematode *Globodera rostochiensis* Ro1. |
| 12-18 June | XIVth International Symposium on Fruit Tree Virus Diseases and Vth International Symposium on Small Fruit Virus Diseases, Thessaloniki, Greece | |
| | A. T. Jones<br>(M. J. Mitchell)<br>(A. N. E. Birch)<br>(D. J. F. Brown)<br>(D. L. Jennings) | Recent research on the control of virus infections in raspberry in Britain. |

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| 22-23 June | ADAS/SCRI Potato Workshop, High Mowthorpe EHF | |
| | H. V. Davies | Markers for maturity in the potato crop. |
| | D. K. L. MacKerron | Factors affecting seed sprouting. |
| | B. Marshall | The way forward in experimentation and application of seed rate recommendations. |
| 3-9 July | XVIII International Congress of Entomology, Vancouver, B.C., Canada | |
| | S. C. Gordon (J. A. T. Woodford) (I. A. Barrie[1]) | Predicting emergence of overwintered *Resseliella theobaldi* (Barnes, Diptera, Cecidomyiidae) to control 'Midge Blight' in red raspberry. |
| 10-13 July | ODA Natural Resources Conference, University of Warwick | |
| | N. L. Innes | Biotechnology and plant breeding. |
| 11-15 July | 11th Conference of the International Soil Tillage Research Organisation, Edinburgh | |
| | B. Boag | Influence of ploughing, rotary cultivation and soil compaction on migratory plant parasitic nematodes. |
| 18-22 July | XIVth International Biometrics Conference, Namur, Belgium | |
| | C. A. Glasbey | Lamb carcass composition estimated by image processing of X-ray computed tomography. |
| 25 July | ADAS Oilseed Rape Wildlife Meeting, University of Newcastle-upon-Tyne | |
| | D. W. Griffiths (W. H. Macfarlane-Smith) (B. Boag) | Initial observations on the effect of wildlife grazing on double-low oilseed rape in Scotland. |
| 28 July | PMB/SAC/SCRI Conference on Newer Techniques in Potato Production, SCRI, Dundee | |
| | H. V. Davies | Markers for maturity in the potato crop. |
| | G. R. Mackay | Targets in potato breeding. |
| | D. K. L. MacKerron | Planting rates — the effect on final grade distribution. |

[1]Meteorological Office, MAFF, Wolverhampton

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| 2-5 August | 7th Meeting of the EUCARPIA Section Biometrics in Plant Breeding, Ås, Norway | |
| | J. E. Bradshaw | The relative merits of lines versus hybrids in swedes (*Brassica napus* L. ssp. rapifera). |
| 7-13 August | XIX International Symposium of the European Society of Nematologists, Uppsala, Sweden | |
| | B. Boag<br>(T. J. W. Alphey) | Can interspecific competition be utilised to control plant-parasitic nematodes? |
| | B. Boag<br>(D. J. F. Brown) | Optimum sampling procedures for the detection of low numbers of virus-vector nematodes. |
| | D. J. F. Brown | Proposal to establish a European Working Party to collaborate in a study of tobraviruses and their vector trichodorid nematodes. |
| | D. J. F. Brown<br>(A. T. Ploeg)<br>(D. J. Robinson) | Comments on the natural association between serological and symptomatological variants of tobacco rattle virus and some *Trichodorus* and *Paratrichodorus* species. |
| | D. J. F. Brown<br>(B. Boag)<br>(A. T. Jones)<br>(P. B. Topham) | Field sampling density for detecting nepo and tobraviruses transmitted by longidorid and trichodorid nematodes. |
| | J. M. S. Forrest<br>(W. M. Robertson)<br>(E. W. Milne) | Cell wall breakdown close to the feeding site in potatoes resistant to *Globodera rostochiensis* |
| | W. M. Robertson<br>(J. M. S. Forrest) | Lectin labelling of *Longidorus elongatus* |
| 14-19 August | 4th International Diffuse Reflectance Conference, Chambersburg, Pennsylvania, USA | |
| | I. A. Cowe<br>(J. W. McNicol)<br>(D. C. Cuthbertson) | "Prospector", Principal Component Analysis of NIR spectra using a Microcomputer |
| 20-27 August | 5th International Congress of Plant Pathology, Kyoto, Japan | |
| | B. D. Harrison<br>(M. M. Aiton)<br>(A. M. Lennon)<br>(I. M. Roberts) | Two new cassava viruses from Africa. |

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| | B. D. Harrison<br>(M. M. Aiton)<br>(V. Muniyappa) | Epitope variation in tobacco leaf curl virus. |
| | B. D. Harrison<br>(M. M. Aiton)<br>(V. G. Malathi)<br>(V. Muniyappa) | Variation in Indian cassava mosaic virus studied with monoclonal antibodies. |
| | A. F. Murant<br>(D. J. Robinson)<br>(J. H. Raschke)<br>(R. Rajeshwari) | Recent findings on viruses that depend on luteoviruses for transmission by aphids. |
| | M. C. M. Pérombelon | Sources and pathways of contamination of potatoes by soft rot erwinias. |
| | D. L. Trudgill<br>(B. Boag)<br>(W. M. Robertson) | Host recognition of plant-parasitic nematodes by ectoparasitic fungi. |
| | D. L. Trudgill<br>(D. J. F. Brown)<br>(W. M. Robertson) | Specificity of transmission of nepo and tobraviruses. |
| | D. L. Trudgill<br>(D. J. F. Brown)<br>(F. Lamberti[1])<br>(C. E. Taylor) | Nematode-virus plant interactions |
| | D. L. Trudgill<br>(M. S. Phillips) | Potato cyst nematode, effects of plant resistance and nematode genetics on population dynamics. |
| 9-10 September | 2nd Nordic Cell and Tissue Culture Meeting | |
| | W. Powell<br>(S. J. Finnie)<br>(K. Chalmers)<br>(R. Waugh)<br>(B. P. Forster)<br>(R. J. Abbot[2])<br>(E. Baird) | The development and utilisation of anther culture technology in barley breeding. |
| 11-16 September | EUCARPIA Congress, Genetic Manipulation in Plant Breeding Biotechnology for the Breeder | |
| | J. Brown[3]<br>(R. Waugh)<br>(A. Kumar)<br>(W. Powell) | Gene splicing in plants. |

[1]Instituto Nematologia Agraria, Bari, Italy
[2]Department of Pre-clinical Medicine, University of St. Andrews
[3]Department of Biological Sciences, University of Dundee

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| 12-16 September | International Geoscience and Remote Sensing Symposium, Edinburgh | |
| | C. A. Glasbey | Normal distributional assumptions in discrimination. |
| 13-17 September | European Weed Research Society XIIIth International Symposium on Biology, Ecology and Systemics of Weeds | |
| | H. M. Lawson<br>(G. McN. Wright)<br>(N. T. Smoktunowicz) | Weed seed populations in swede turnip fields in Scotland. |
| 15-16 September | AFRS Statisticians Meeting, Reading | |
| | J. W. McNicol | Principal Component Analyses of Near Infra Red Spectra. |
| 15-17 September | Effects of Crop Rotation on Potato Production in Temperate Zones | |
| | M. S. Phillips<br>(D. L. Trudgill) | The role of cyst nematodes in crop rotations in potato. |
| 18-21 September | Association of Applied Biologists. Environmental Aspects of Applied Biology, York | |
| | G. R. Mackay | Progress towards disease and pest resistant potatoes. |
| | M. F. B. Dale | Breeding for tolerance to potato cyst nematode. |
| | Miss H. E. Stewart<br>(J. Brown)<br>(R. L. Wastie) | The effect of late blight on yield and yield components of potato. |
| | A. T. Jones | The influence of cultivating new raspberry varieties on the incidence of viruses in raspberry crops in the UK. |
| | J. A. T. Woodford | The impact of cropping policy on methods to control potato leafroll virus. |
| 19-21 September | SEB/Plant Transport Group meeting, Gregynog, Wales | |
| | K. J. Oparka | Turgor-sensitive sucrose uptake and partitioning in potato tuber storage parenchyma. |
| 19-22 September | Nitrogen in Organic Wastes Applied to Soil, Aalborg, Denmark | |
| | B. S. Griffiths | The effect of protozoan grazing on nitrification — implications from the application of organic wastes applied to soil. |

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| 19-22 September | British Mycological Society/British Society for Plant Pathology, University of Sussex | |
| | J. M. Duncan | Inoculum potential in diseases caused by *Phytophthora*. |
| | B. Williamson | Inoculum potential of *Botrytis* on woody hosts. |
| 19-22 September | British Ecological Society Symposium on Plant Root systems, University of Aberdeen | |
| | D. Robinson<br>(S. Buchan)<br>(F. Smith) | Estimating root length by image analysis. |
| | D. Robinson | Roots and resource fluxes in plants and communities. |
| 20-21 September | EEC Expert Group on Oilseed Rape and Wildlife, Brussels, Belgium | |
| | W. H. Macfarlane-Smith<br>(D. W. Griffiths)<br>(B. Boag) | Glucosinolate content and S-methyl cysteine sulphoxide (SMCO) content of green tissue of various *Brassica* spp. |
| | B. Boag<br>(W. H. Macfarlane-Smith)<br>(D. W. Griffiths) | Observations on the grazing of two fodder rape varieties by the wild rabbit *Oryctolagus cuniculus* in Scotland. |
| 26 October | Workshop on Barley for Malting, Redhill, Surrey | |
| | M. J. Allison | Development of rapid malting-barley evaluation tests on the micro scale. |
| 27-28 October | European and Mediterranean Plant Protection Organisation Conference on Soil-borne Viruses and their Vectors, Malmo, Sweden | |
| | B. Boag<br>(D. J. F. Brown) | Optimising sampling strategies for nematode-transmitted viruses and their vectors. |
| | B. Boag<br>(D. J. F. Brown) | Sampling strategies for nematode-transmitted viruses and their vectors. |
| | D. J. F. Brown | Viruses transmitted by nematodes. |
| | D. J. F. Brown<br>(D. L. Trudgill) | Nepoviruses and their vector nematode associated with grapevines and fruit trees in Europe. |

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| | D. J. F. Brown<br>(A. T. Ploeg)<br>(D. J. Robinson) | The association between serotypes of tobacco rattle virus and *Trichodorus* and *Paratrichodorus* species. |
| | A. T. Ploeg<br>(D. J. F. Brown)<br>(D. J. Robinson) | Transmission of TRV by trichodorid nematodes. |
| | D. J. Robinson | Tobacco rattle virus: variation among strains and detection by cDNA probes. |
| | L. Torrance | Properties of monoclonal antibodies to beet necrotic yellow vein virus. |
| 11 November | VTSC Growers Association Conference, Aviemore | |
| | D. A. Perry | Improving seed potato health. |
| 21-24 November | 1988 British Crop Protection Conference — Pests and Diseases, Brighton | |
| | D. J. Robinson | Prospects for the application of nucleic acid probes in plant virus detection. |
| 1 December | Signal Processing in Molecular Spectroscopy, London | |
| | J. W. McNicol<br>(I. A. Cowe)<br>(D. C. Cuthbertson) | Principal Component analysis of Near Infra Red Spectra. |
| 11-16 December | Joint Meeting EUCARPIA Potato Section/EAPR Breeding and Varietal Assessment Section, Wageningen, The Netherlands | |
| | G. R. Mackay | Parental line breeding at the tetraploid level. |
| | M. F. B. Dale | Resistance to and tolerance of potato cyst nematode as objects within a breeding programme. |
| | M. J. De, Maine | Using dihaploids to increase homozygosity in tetraploid potatoes. |
| 12-13 December | IBC Conference on Biotechnology, Cambridge | |
| | B. D. Harrison | Virus resistant transgenic plants. |
| 13-14 December | 5th Workshop on Nitrogen in Soils, Silsoe | |
| | B. S. Griffiths | Effects of protozoan/nematode grazing on N mineralization. |
| | K. Ritz | Problems associated with measuring temporal variations in biomass nitrogen. |

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| | D. Robinson<br>(B. Griffiths)<br>(K. Ritz)<br>(R. Wheatley) | Can roots supply themselves with nitrogen? |
| | R. E. Wheatley | The production of nitrous oxide in soils. |
| 13-15 December | British Society for Plant Pathology, University of Reading | |
| | R. S. Forrest | HPLC detection and purification of phytoalexin-eliciting oligosaccharides released from potato cell walls by bacterial polygalacturonic acid lyases. |
| 21 December | Plant Breeding to Control Nematodes — Theory and Practice, Wolverhampton | |
| | J. M. S. Forrest | Fundamental aspects of potato/nematode relations. |
| | M. S. Phillips<br>(D. L. Trudgill) | PCN: virulence and resistance. |
| 22 December | British Ecological Society Winter Meeting, Newcastle | |
| | R. A. Kempton<br>(C. A. Hackett)<br>(M. S. Phillips) | Population regulation of potato cyst nematode. |

*Conferences organised*

D. J. F. Brown was joint organiser of an EPPO conference on soil-borne viruses held in Alnarp, Sweden, 27-29 October. He also organised a British Council sponsored weekend workshop from 29-31 October on soil-borne viruses of potato held in Malmo, Sweden.

M. F. B. Dale was a Member of the Organising Committee for AAB conference on environmental aspects of applied biology, York, 19-21 September.

G. H. Duncan was a joint organiser of the 16th Scottish Symposium on Electron Microscope Techniques held at the University Medical School, Dundee on 16 November.

D. K. L. MacKerron and R. J. A. Exley jointly with SAC and PMB organised the conference 'Newer techniques in potato production', SCRI, Dundee, 28 July.

D. A. Perry organised a meeting on Coordination of research and development on potato pathology at University of Dundee, 27-28 September.

D. Robinson was a co-organiser of the British Ecological Society Symposium on plant root systems, University of Aberdeen, 19-22 September.

M. Talbot organised an International Workshop of the Union for the Protection of New Varieties of Plants (UPOV) Working Party on Automation and Computer Programs.

L. Torrance organised the session on 'Diagnostic Aids in Crop Protection' at the British Crop Protection Conference — Pests & Diseases held on 21-24 November.

*Courses attended*

B. Alexander, Angela Monaghan, J. S. Wiseman, Mrs Gladys McN. Wright attended courses on the safe use of pesticides and hand-held applicators provided by the Sidlaw Training Group in cooperation with ATB, 10-12 May.

A. Booth and A. Young attended an Agricultural Training Board course on Pesticide Application, SCRI, 10-11 May.

I. M. Chapman attended a Potato Roguers' course ASS (East Craigs), Edinburgh, 20 June to 1 July.

G. Dow, G. Pugh and E. Watt attended courses on the safe use of Pesticides and hand-held applicators (knapsack) organised by Sidlaw Training Group in co-operation with ATB, 5 and 7 December.

G. Dunlop attended a course for Meteorological Observers, at the Meteorological Office, Edinburgh, 23-24 September.

R. P. Ellis and G. R. Young attended a SASS course on the use of MINITAB, SCRI, 30-31 May.

I. Fleming, J. P. T. Grant and J. Mason attended courses on the safe use of pesticides and field crop sprayer (Hydraulic nozzle) organised by Sidlaw Training Group in co-operation with ATB, 21 and 23 November.

J. M. S. Forrest attended a course on Plant Molecular Biology held at Wye College, University of London, 4-15 July.

D. T. Mason attended a first aid course organised by the Red Cross in Dundee, 25-28 April.

G. G. Pollock attended a field machinery common tasks course, organised by Sidlaw Training Group in co-operation with ATB, 24-31 May.

J. Robb and D. Stewart attended courses on Electrophoresis at IACR (Rothamsted Experimental Station) 7-8 April, and a Protein Workshop at Hatfield Polytechnic, 5-6 September.

W. M. Robertson participated in a Protein Workshop, Hatfield Polytechnic, 12-13 September.

Heather A. Ross attended a molecular biology update at Hatfield Polytechnic, 28-31 March.

G. E. L. Swan attended an Agricultural Chemicals safety course, SCRI, (Agricultural Training Board), 10-12 May.

R. L. Wilson attended courses on the safe use of pesticides and fieldcrop sprayer (Hydraulic nozzle) organised by Sidlaw Training Group in cooperation with ATB, 2 and 8 June, and 23 November, 1988.

*Courses Organised or Contributed to*

B. Boag contributed a demonstration of computer identification of cyst nematodes to an Association of Applied Biologists Workshop on the identification of cyst nematodes at IACR (Rothamsted Experimental Station) 17-19 February.

R. M. Brennan gave a lecture on Progress in the Breeding of Black Currants to the AGM in London of the Pattenden Marketing Association on 18th March.

D. J. F. Brown lectured to the Plant Virus Epidemiology Course at SCRI on Mechanisms and Specificity of Virus Transmission by Nematodes, 27 July

M. Coleman lectured to students at the Universities of Dundee and St. Andrews on cell and tissue culture methods in crop improvement.

B. P. Forster lectured to students at the University of Dundee on the application of chromosome genetics to crop improvement.

S. C. Gordon lectured on the Arthropod Pests of Cane and Bush Fruits on 19 July to the Pacific Northwest Small Fruits Extension/Research Tour, Vancouver, B.C., Canada.

J. R. Hillman gave lectures in developmental physiology and botany to undergraduate students in the Universities of Dundee and Strathclyde.

A. Kumar lectured to students at the University of Dundee on strategies for the use of biotechnology in crop improvements, and students from University of Aberdeen on the cellular and molecular basis of crop improvement.

G. R. Mackay organised a Lecture Course on plant breeding to students of Biology and Preclinical Medicine, University of St. Andrews, 8-12 March, and gave a course of lectures on potato breeding to biology students at University of Dundee in March.

D. K. L. MacKerron lectured on physiological determinants of yield in potatoes to honours students in Agriculture, University of Aberdeen, 10 March. He gave two lectures, 'Crop Response to Environment' and 'Water/Plant Relations' to students at the Seed Potato Course, Edinburgh School of Agriculture, 4 and 7 July. He lectured on 'Potato tuber, size and number' at the ADAS National Potato Advisory Course, Sutton Bonington, 19 July. He also gave a talk to Grampian Growers on 'Influence of temperature on development in potato', 12 December.

B. Marshall organised a half day workshop at the University of Wageningen on the use of the ADC portable gas analysis system in field and laboratory measurements of carbon dioxide and water exchange, 5 October.

S. Millam lectured to students at the University of St. Andrews on biotechnology and crop improvement.

W. Powell lectured to students at the Universities of St. Andrews and Dundee on aspects of plant genetic manipulation.

SASS staff provided several courses on 'Basic Statistics using Minitab' and 'Introduction to Genstat 5' during the year for DAFS scientists.

R. Waugh lectured to students at the Universities of Dundee and St. Andrews on the role of molecular techniques in crop improvement.

R. L. Wastie lectured on Erwinia diseases to ESCA Seed Potato Production course, 15 July.

J. S. Wiseman organised a short refresher course for members of staff preparing for national Proficiency Tests in Pesticides Application (hand held applicators), 17 November.

J. A. T. Woodford contributed a lecture and a practical on 'Potato Aphids' and the 'Control of Aphid-borne Viruses' to the Pests Module of the BASIS training course, WSAC, Auchincruive, 20 October.

Virology Department staff gave lectures and demonstrations in a short course on plant virology for students at the University of Dundee in February-March, and provided lectures and demonstrations at SCRI on 26-27 July for the Scottish leg of a British Council course on Plant Virus Epidemiology, intended primarily for plant virologists from foreign, especially developing, countries.

*Editorial Duties*

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| J. M. Duncan | Associate Editor of *Journal of Horticultural Science* |
| B. D. Harrison | Editor of *Association of Applied Biologists Descriptions of Plant Viruses* |
| J. R. Hillman | Editor of *Crop Research* |
| | Member of the Publication Committee of *Journal of Horticultural Science* |
| | Member of Editorial Panel *Agricultural Systems* |
| T. Hodgkin | Joint Editor of *EUCARPIA Cruciferae Newsletter* |
| N. L. Innes | Member of Editorial Board of *AgriBiotech News and Information* |
| H. M. Lawson | Associate Editor of *Journal of Horticultural Science.* |
| G. R. Mackay | Member of Editorial Board of *Heredity* |
| D. K. L. MacKerron | Associate Editor of *Journal of Horticultural Science* |
| M. A. Mayo | Editor (plant virology) of *Journal of General Virology* |
| A. F. Murant | Editor of *Association of Applied Biologists Descriptions of Plant Viruses* |
| | Member of Editorial Board of *Intervirology* |
| D. A. Perry | Member of Editorial Board of *Crop Research* |
| W. Powell | Member of Editorial Board of *Heredity* |
| | Member of Editorial Board of *Potato Research* |
| D. Robinson | Associate Editor of *Journal of Horticultural Science* |
| D. J. Robinson | Member of Editorial Board of *Journal of Virological Methods* |
| | Member of Editorial Board of *Journal of General Virology* |
| D. L. Trudgill | Consulting Editor of *Plant and Soil* |

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| P. D. Waister | Associate Editor of *Journal of Horticultural Science* |
| | Associate Editor of *Crop Research* |
| A. B. Wills | Joint Editor of *EUCARPIA Cruciferae Newsletter* |
| B. Williamson | Member of Editorial Board of *Annals of Applied Biology* |
| J. A. T. Woodford | Member of Editorial Board of *Annals of Applied Biology* |

*Service on Committees*

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|---|---|
| H. Barker | AAB Virology Group Committee |
| B. Boag | Nematological and Scottish Representative on the European Invertebrate Survey Committee |
| R. M. Brennan | NFT Black Currant and Bush Fruit Panel |
| D. J. F. Brown | Secretary and Treasurer of the European Society of Nematologists |
| S. T. Buckland | Scientific Committee of International Whaling Commission |
| M. R. Cormack | NFT Scottish Soft Fruit Panel |
| | SCRI/ASS/COSAC Liaison Committee Soft Fruit Working Group |
| | Adviser to SDA/TRIO Industrial Group raspberry machine harvesting |
| M. F. B. Dale | Convener of plant breeding Committee of AAB and Member of Council |
| H. V. Davies | British Plant Growth Regulator Group Committee |
| J. M. Duncan | BSPP — Membership Secretary |
| R. P. Ellis | SSCR Technical Secretary Cereals Group |
| | BSPB Cereal Crop Group |
| | BSPB Representative SAC Recommended List Consultative Committee |
| M. F. Franklin | Biometric Society Committee |
| P. A. Gill | Institute of Horticulture — Secretary of Scottish Branch |
| | Chairman of SCRI section of IPCS |
| S. C. Gordon | Member of AFRC Pesticide Application Discussion Group and AAB Pesticide Application Group Committee |
| B. D. Harrison | Advisory Committee, *Advances in Virus Research* |
| | Virology Programme Committee, International Congress of Plant Pathology |
| | Advisory Committee for NERC Institute of Virology, Oxford |

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| J. R. Hillman | AFRC Plants and Soils Research Committee |
| | AFRC Computing Committee |
| | DAFS Joint Management Board |
| | Organising Committee for EAPR Triennial Conference 1990 |
| | ECRE Board of Management |
| | GIUS, WSC, Technical Committee |
| | Horticultural Quartet |
| | NFT (Brogdale) Advisory Committee |
| | Publications Committee, *Journal of Horticultural Science* |
| | Royal Society of Edinburgh (Sectional Committee B) |
| | Chairman SCRI/ASS/COSAC Liaison Group |
| | SNSA Adviser to Committee |
| | Strategic Quintet (ADAS/AFRC/SAC/SARI) |
| | Chairman Crop Production Quartet |
| | Senate, Dundee University |
| | External Examiner in B.Sc. Biological Sciences, Lancaster University |
| | Chairman Tayside Biocentre Group |
| | University of Strathclyde Sub-Board for the Degree of B.Sc. in Horticulture |
| N. L. Innes | Governing Board, ICRISAT, India |
| | Chairman, Programme Committee, ICRISAT |
| | Governing Board, CIP, Peru |
| | Horticultural Quartet (ADAS/AFRC/SAC/SARI) |
| | BSPB Technical Advisory Committee |
| | University of Dundee Botanic Garden Committee |
| | UK Plant Genetic Resources Group |
| | SCRI/ASS/COSAC Liaison Group |
| D. L. Jennings | NFT Raspberry Panel |
| | NFT Scottish Soft Fruit Panel |
| | SNSA Adviser to Committee |
| | Fruit Research Consultative Committee |
| A. T. Jones | Secretary of ISHS Working Group on Virus Diseases of Small Fruits and Chairman of the Group from July |
| R. A. Kempton | Royal Statistical Society Council |
| | Royal Statistical Society Research Committee |
| H. M. Lawson | ADAS/IACR(LARS) (Weed Division) Liaison Group |
| | AFRC Fruit Weed Control Group |
| | BCPC R&D Sub-committee — Weeds |
| | Member of ADAS Brogdale EHS Visiting Group |
| | SAC/SCRI Weeds Group |
| G. D. Lyon | SEB — Member of Cell Signalling Group |

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| W. H. Macfarlane Smith | BSPB Oilseed and Industrial Crop Group<br>NPTC Plant Variety Development Panel<br>Secretary SCRI/ASS/SAC Forage Brassica Working Group<br>Secretary SCRI/SSCR Forage Crop Sub-committee<br>Technical Secretary Sectoral Quartet on Crop Production |
| G. R. Mackay | EAPR 1990 Triennial Congress, Scientific Committee member<br>Member Interdepartmental and Users' Committee of DAFS breeders' quarantine unit<br>Member DAFS potato working group<br>Member BSPB potato crop group<br>Chairman EUCARPIA potato section |
| D. K. L. MacKerron | Secretary DAFS Potato Working Group<br>Secretary SSCR Potato Crop Sub-Committee<br>Chairman Working Group on Water Relations in Potato Production, EAPR Physiology and Agronomy Sections<br>Chairman of Scientific Committee for EAPR Triennial Conference, 1990<br>SCRI/ASS/COSAC Liaison Group |
| B. Marshall | SEB Plant Biology Section Committee |
| M. A. Mayo | International Committee on Taxonomy of Viruses, Executive Committee |
| W. P. Mowat | Convener, SNSA Bulb Technical Committee |
| A. F. Murant | International Committee on Taxonomy of Viruses, Member of Plant Virus Sub-Committee |
| R. J. McNicol | NFT Strawberry Panel<br>NFT Scottish Soft Fruit Panel<br>NFU Strawberry Breeding Sub-committee to the Soft Fruit Committee<br>Scottish Soft Fruit Working Group |
| A. C. Newton | UK Cereal Pathogen Virulence Survey Committee Member |
| M. C. M. Pérombelon | ISPP — Chairman International Erwinia (soft rot) Group |
| D. A. Perry | Treasurer, Association for Crop Protection in Northern Britain<br>Chairman, Scottish Potato Disease Working Party |
| G. Ramsay | BSPB Oilseed and Industrial Crop Group<br>SAC/SARI Oil and Protein Crop Working Group<br>Secretary SCRI Faba Bean Working Party |

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| I. M. Roberts | Chairman, AFRC Electron Microscope Advisory Group<br>Safety Representative, Royal Microscopical Society Education Committee<br>Scientific Organisation Committee, European Electron Microscope Conference (Eurem 88), York |
| L. Torrance | Committee for COST project 88 on early detection of plant diseases |
| P. D. Waister | Chairman, DAFS Potato Working Group<br>Co-chairman, EAPR Working Group on Tuber Numbers<br>SCRI/ASS/COSAC Liaison Group<br>University of Dundee Botanic Garden Committee |
| R. L. Wastie | Convener of Scottish Mycology and Plant Pathology Club |
| Cynthia J. Williamson | Technical Secretary, SARI/SAC Working Group on Organic Production Systems |
| J. A. T. Woodford | Scottish Regional Secretary, Royal Entomological Society of London. |

*Exhibitions and Poster Sessions*

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| 15-19 March | *Eurotech Scotland,* Glasgow<br>Information Technology in Agriculture |
| 11-14 April | *SEB Meeting,* University of Lancaster<br>Antioxidant status and calcium related disorders of potato tubers |
| 10 May | *AAB Meeting on Implications of genotype and environment interactions,* NIAB Cambridge<br>Are genotype and environment interactions demonstrable for drought tolerance in potato? |
| 30 May-4 June | *10th International symposium on Sexual Reproduction in Higher Plants*<br>Interspecific incompatibility between *Brassica napus* and *B. oleracea* |
| 12-16 June | *27th Annual Meeting of the Society of Nematologists,* Raleigh, N.C., USA<br>The nematicidal potential of natural plant products<br>Lectin labelling of *Longidorus elongatus*<br>The specificity of nematophagous fungi for plant-parasitic nematodes<br>Computer identification of cyst nematodes |
| 11-15 July | *11th Conference of the International Soil Tillage Research Organisation,* Edinburgh<br>Influence of ploughing, rotary cultivation and soil compaction on migratory plant-parasitic nematodes |

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| | Physical properties of two structurally sensitive soils and their effects on group growth<br>Use of low friction penetrometers to estimate soils resistance to root growth<br>Video presentation of stolon development and root dynamics |
| 28 July | *SCRI/SAC/PMB Meeting, Newer techniques for Potato Production,* SCRI, Dundee<br>Nitrogen nutrition of potato |
| 7-13 August | *XIX European Society of Nematologists International Symposium,* Uppsala, Sweden<br>Application of immunological techniques in plant nematology<br>Surface components of *Longidorus elongatus*<br>Assessment of the nematicidal properties of natural plant products<br>Optimum sampling procedures for the detection of low numbers of virus vector nematodes<br>Host recognition of plant-parasitic nematodes by the nematophagous fungus *Arthrobotrys dasguptae*<br>Plant-parasitic nematodes associated with cereals in Scotland |
| 20-27 August | *5th International Congress of Plant Pathology,* Kyoto, Japan<br>Amino acid sequence comparisons between potato leafroll and beet western yellows luteoviruses<br>Recognition of plant-parasitic nematodes by ectoparasitic fungi<br>Wheat-germ agglutinin association with the outer cuticle of the wheat-gall nematode, *Anguina tritici* |
| 6 September | *2nd Annual SAC Plant Physiologists/Biochemists Conference,* Aberdeen<br>Stem production in export potato cultures |
| 11-16 September | *EUCARPIA Congress, Genetic Manipulation in Plant Breeding Biotechnology for the Breeder*<br>Biochemical and molecular markers in potato improvements |
| 13 September | *PMB Potato Harvesting and Handling Demonstration,* Norwich<br>Hot water treatment for blackleg control<br>Breeding for resistance to potato cyst nematodes<br>Internal rust spot and potato calcium deficiency<br>Tissue culture of potato and genetic fingerprinting |

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| 15-17 September | *Sektion Virologie der Deutschen Gesellschaft für Hygiene und Mikrobiologie* and the *Society for General Microbiology*, Hamburg, FRG.<br>Multiplication of raspberry ringspot virus in *Nicotiana* protoplasts |
| 19-22 September | *British Ecological Society Symposium*, Aberdeen<br>Effects of particle size distribution on maize root growth in pressurised beds of ballotini and sand<br>Video presentation of root dynamics |
| 6 October | *Data Capture and Handling Meeting*<br>Association of Applied Biologists, Churchill College Cambridge<br>Demonstration of CHIP |
| 11-12 October | *SCOTGROW 1988*, Ingliston, Edinburgh<br>New fruit crops for the UK<br>Novel crops for the UK |
| 16 November | *16th Scottish Symposium on Electron Microscope Techniques*, Dundee<br>Cryo-trimmed, freeze-dried raspberry drupelet infected by *Botrytis cinerea* |
| 13-15 December | *British Society for Plant Pathology*, Reading<br>Enhancement of barley mildew resistance using yeast cell wall extracts and other elicitors |

*Radio and Television*

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| 1st February | *BBC Schools Radio, 'The Mighty Spud'* | |
| | G. R. Mackay | Breeding new cultivars of crisping potatoes |
| 23 February | *Radio Tay* | |
| | H. M. Lawson | Replacement of dinoseb for the control of cane vigour |
| 11 March | *BBC Radio Scotland, 'Head on'* | |
| | M. R. Cormack | The future of soft fruit in Scotland |
| 16 July | *BBC TV, 'Landward'* | |
| | D. L. Jennings | A new raspberry cultivar that does not require cane vigour control |
| 17 July | *BBC TV, 'Landward'* | |
| | D. L. Trudgill | Progress in breeding for resistance to the white species of potato cyst nematode |
| 31 August | *Radio Tay, 'Discovery 2000'* | |
| | P. D. Waister | Prospects for fibre crops |
| 20 September | *Radio Tay, 'Discovery 2000'* | |
| | P. D. Waister | Potato studies |

PU 01 Develop enhanced germplasm of the potato and more effective means of genetic manipulation and plant breeding

(a) Produce enhanced potato germplasm suitable for use by industry within the UK.
(b) Identify potato germplasm of value to the UK seed potato export industry.
(c) Study the genetics, explore and exploit emergent techniques and conventional breeding/selection methods of the potato.
(d) Develop new breeding material from primitive and novel germplasms.
(e) Improve, and use, screening methods for resistance and tolerance to pests and diseases of potatoes.
(f) Develop and use screening tests for selected biochemical compounds in potatoes.
(g) Maintain and evaluate the Commonwealth Potato Collection.

PU 02 Develop enhanced germplasm in cereals and more effective means of genetic manipulation and plant breeding

(a) Develop enhanced germplasm of spring barley with durable disease resistance and good malting quality.
(b) Develop enhanced germplasm of winter barley with durable disease resistance and good malting quality.
(c) Study biochemical genetics of barley.
(d) Study genetics of barley and improve breeding technology.
(e) Improve screening methods for fungal disease resistance in barley breeding material.
(f) Develop rapid test for malting quality.
(g) Trial extension crops.
(h) Development of experimental techniques.

PU 03 Develop enhanced germplasm in soft fruit and more effective means of genetic manipulation and plant breeding

(a) Produce improved cultivars of raspberry and study relevant characters.
(b) Provide improved cultivars of black currant and study relevant characters.
(c) Provide improved cultivars of blackberries and other Rubus fruits.
(d) Identify and breed strawberry genotypes including some from the IHR programme, adapted to the Scottish environment.
(e) To evaluate cultivars of novel fruits and rectify shortcomings by breeding where appropriate.

PU 04 Develop enhanced germplasm in Brassica crops and more effective means of genetic manipulation and plant breeding

(f) Multiply and stabilise breeder's selections: and trial selections in collaboration with other organisations.
(g) Investigate novel combinations of genomes to produce breeding materials.
(h) Investigate tissue culture and use to produce new breeding materials.
(i) Study genetics of brassicas and formulate genotype improvement strategies.
(j) Study S-allele incompatibility in brassicas.
(k) Locate and assess resistance to fungal and virus diseases.
(l) Develop and use screening tests for important compounds in brassica breeding material.
(m) Improve Brassica root crop germplasms.
(n) Improve leafy forage brassica germplasms.
(o) Develop and evaluate screening tests for resistance to turnip root fly.

PU 05 Potato physiology

(d) Mathematical analysis and modelling of plant and crop processes.
(h) Quantify the effects of temperature and radiation on development and growth in the potato crop.
(i) Water-related stresses in potato production.
(j) Physiological processes involved in phloem unloading and control of sink strength in potato tubers.
(k) Control of dormancy, apical dominance and sprout growth in potato tubers.
(l) Physiological processes governing nitrogen utilisation by the potato plant.
(m) Potato tuber quality — control of reducing sugar accumulation and calcium-related internal disorders.
(n) Effects of agrochemical contamination and misuse on the growth, yield and quality of seed potatoes.
(o) Mechanisms of xenobiotic transport.
(p) Effects of cultural practices on the growth and development of the potato crop.
(q) Inputs required by mathematical model to predict the national potato crop.

PU 06 Husbandry of soft fruits

(b) Dry matter partitioning, and compensation between yield components in cane fruits.
(c) Physiological and cultural factors affecting the mechanical harvesting of soft fruits.
(d) Evaluate cultivars and design production methods for raspberry, other Rubus, blueberry and novel bush fruit species.

PU 08 The biology and control of diseases and pests of cereal crops in Northern Britain

(a) Investigate the biology of winter diseases of barley.
(b) Investigate the biology of leaf diseases to improve control strategies.
(c) Investigate the extent of damage by cereal cyst nematode and its control.

PU 09 The biology and control of diseases and pests of soft fruit crops in Northern Britain

(a) Study the biology of fungal and bacterial diseases of soft fruit.
(b) Prediction and control of insect and mite pests of cane fruits.
(c) Elucidate the role of nematodes in planting disorders, reduce losses and improve control.
(d) Study properties, spread and control of Rubus viruses and devise diagnostic methods.
(e) Produce virus-free stocks, assess virus resistance and index British and imported raspberry and other Rubus genotypes.
(f) Study the properties of, and devise diagnostic tests for, reversion and other viruses infecting black currant.
(g) Determine the cause of, and devise diagnostic methods for, June Yellows of strawberry.
(h) Produce and maintain virus-free stocks of black currant.

PU 10 The biology and control of diseases and pests of Brassica crops

(a) Study the biology of fungal diseases of brassica crops.
(c) Investigate the pathogenicity and control of nematode pests of forage brassicas.
(e) Develop biological methods of control of *Plasmodiophora brassicae*.

PU 11 The biology and control of diseases and pests of narcissus crops in Northern Britain

(a) Devise detection methods and determine properties and epidemiology of narcissus viruses.
(b) Maintain virus-free stocks of narcissus, and monitor health during field propagation.

PU 12 The biology and properties of non-indigenous plant viruses

(a) Devise diagnostic methods for, and characterise, whitefly-transmitted viruses from cassava and other tropical crops.
(b) Determine epidemiology, detection and assay methods for groundnut rosette and groundnut rosette assistor viruses.

PU 13 The biology and control of diseases and pests of potatoes

(a) Study the biology and pathogenesis of bacterial diseases of potato plants.
(b) Study the biology of bacterial diseases of stored potato tubers.
(d) Elucidate survival of potato pathogens by studying their autecology.
(e) Improve methods of forecasting diseases of potato.
(f) Ecology of aphid vectors and epidemiology of aphid-borne potato viruses.
(h) Improve management of nematodes in seed and ware land and reduce damage in ware land.
(j) Understand and assess effectiveness and determine inheritance of virus resistance mechanisms in potato.
(k) Develop virus detection methods; study relationships, transmission by vectors and properties of potato viruses.
(l) Mechanisms and genetic basis of virulence in potato cyst nematodes.
(m) Development of immunobiological methods for detecting fungal pathogens.

PU 18 Yield and quality in grain legumes

(a) Effects of environment and genotype on development, growth and quality of field beans.
(b) Develop enhanced germplasm of Vicia beans and more effective means of genetic manipulation and plant breeding.

PU 19 The cellular and molecular basis of crop improvement

(a) Development of stable single cell isolation and regeneration systems.
(b) Exploitation of protoplasts and microspore systems in crop improvements.
(c) Development of *in-vitro* selection strategies.
(d) Introduction of foreign genes into plants (genetic transformation).
(e) Develop strategies for cybrid production and study the segregation of organelles.
(f) Study the inheritance, stability and copy number of gene inserts in transgenic plants.
(g) Study genome organisation and structure at the nucleic acid level.
(h) Construction of detailed genetic linkage maps using molecular (RFLPs) and isozyme markers.
(i) Identify gene insertion sites by *in-situ* hybridization techniques.
(j) Develop and utilize suitable aneuploid stocks for use in genetic linkage studies.
(k) Investigate the cytological status of hybrid cells produced by sexual and somatic hybridisation.
(l) Gene isolation by insertional mutagenesis.

PU 20 Statistical and mathematical services for SARIs, SAC and other organisations

(a) Training scientists in statistics and use of statistical software.
(b) Development and application of new statistical methods.
(c) Statistical computing.
(d) Statistical consultancy and collaborative investigations for HRI.
(e) Statistical consultancy and collaborative investigations for MLURI.
(f) Statistical consultancy and collaborative investigations for MRI.
(g) Statistical consultancy and collaborative investigations for SCRI.
(h) Statistical consultancy and collaborative investigations for RRI.
(i) Statistical consultancy and collaborative investigations for SAC.
(j) Statistical consultancy and collaborative investigations for ASS.
(k) Statistical support for PVRO.

PU 21 Plant fibres

(a) Physical and chemical characteristics of fibre-producing herbs, shrubs and trees.
(b) Control of differentiation and development of fibres.
(c) Factors influencing ease of isolation of fibres.

PU 22 Root growth and the uptake and distribution of water and nutrients

(a) Root growth and distribution in relation to assimilate supply and soil physical and chemical environment.
(b) Potassium uptake, distribution and physiological roles.
(c) Physiological and environmental factors governing nitrogen availability to, and utilisation by, arable crop plants.
(d) Genotype x environment interaction in drought tolerance.

PU 23 Agriculture and the environment

(a) Production, utilisation and rotational value of nitrogen fixing trees and shrubs.
(b) Evaluation of the role of microbial biomass in plant nutrition and effect of root exudates on microbes.
(c) Prediction of weed populations and weed control requirements in crops and rotations.
(d) Biology and population dynamics of plant-parasitic nematodes.
(e) Determine the factors influencing the activity of nematophagous fungi and bacteria attacking nematodes.
(f) Determine the interactions between saprophytic and pathogenic microbial populations in the soil and on plants.

PU 24 Strategic studies on pests and pathogens

(a) Mechanisms of resistance and susceptibility to insects and nematodes.
(b) Effects of vector and host on feeding behaviour in relation to virus transmission by aphids.
(c) Elucidate the role of neurosecretion in the development of nematodes.
(d) Investigate the control of nematode by nematotoxic chemicals.
(e) Identify the vectors of variants of tobraviruses and elucidate the factors governing their inter-relationships.
(f) Elucidate mechanisms of specificity and factors affecting efficiency of nepovirus transmission by nematodes.
(g) Nature and function of nematode and plant pathogenesis related proteins.
(h) Genetic control of pathogenesis and factors affecting changes in physiological races.
(i) Identify and elucidate the effects of pre- and post-formed host and pathogen compounds on disease resistance.
(j) Host and pathogen interactions; factors determining latency and host resistance.

PU 25 Strategic studies on viruses

(a) Elucidate mechanisms of virus transmission by aphids.
(b) Elucidate the genome organisation of viruses and molecular aspects of their biological properties.
(c) Enhance virus resistance by transforming plants with virus-related or virus satellite-related nucleic acid.
(d) Determine structure and function of the genome RNA of potato leafroll virus.
(e) Determine genome organisation of plant picornaviruses.
(f) Understand mechanism of virus transport and intercellular movement in plant tissue.
(g) Develop methods of producing monoclonal antibodies and investigate new uses for them.
(h) Devise and improve methods for the electron microscopy of viruses and virus vectors.
(i) Devise and improve methods for detection and diagnosis of plant viruses and viral materials.

# CEREAL AND LEGUME GENETICS

N. L. INNES

The previous Departmental title of 'Cereal Breeding' was changed to reflect more accurately the switch from cultivar breeding to more fundamental and strategic research. The inclusion of legume research in the Department's programme resulted in a senior appointment to work on the genetics of *Vicia faba* bean.

## New spring barley cultivars [PU 2(a)]

Cv. Tyne continued to perform well in the SAC Regional List Trial series and has been given a general recommendation for growing in Scotland in 1989. It is early maturing, high yielding and has good mildew resistance with malting quality similar to cv. Golden Promise. Plant Breeders Rights for Tyne are now wholly owned by Plant Breeding International, Cambridge.

TS275/3/6 was in NLT year 1 in 1988. It was one of the highest yielding entries in Scottish trials but, despite outyielding the best control, it was one of the lower yielders in English trials. It had good all-round disease resistance but, as it was late maturing and failed DUS tests, it has been withdrawn from statutory trials.

PEG141/4/1/6 performed well in advanced trials and has been submitted for NLT in 1989. It is the first barley to be entered into official trials under the proposed marketing agreement between SCRI and the Consortium of Nickerson Seeds Ltd. and Dalgety Agriculture Ltd. It is a selection from a cross between cultivars Cromarty and Apex and yielded 115% of the mean of cultivars Klaxon and Natasha over 12 trials grown without disease control in 1988. It is short and stiff strawed, possessing the denso dwarfing gene, and has the *ml-o* mildew resistance which, in cv. Atem, has proved durable. It is late heading, due to a very short neck, but reaches maturity only 1 day later than Klaxon. Micro-malting results from trials grown in 1986 and 1987 show that its hot water extract is comparable with that of Natasha.

Eighteen advanced breeding lines and seven control cultivars were grown in a two-replicate nested experiment at Gourdie farm. Additional treatments were, with and without disease control, normal and late harvest. Disease control was achieved with fungicide applications at G.S.30 and G.S.39. The late harvest was 4 weeks later than normal and allowed maximum expression of ear and grain loss. The delay in harvest

had the greatest effect on yield, resulting in an average reduction of 1.1 t/ha (14.7%) compared to normal harvest. Disease control produced an average increase of 0.6 t/ha (8.8%) compared to the untreated mean. The interactions of cultivars with harvest date and disease treatment were significant ($P<0.05$) indicating the presence of differential effects. There was no evidence of any interaction between harvest date and disease treatment so the presence or absence of disease control did not differentially affect yield at the two harvest dates.

(W. T. B. Thomas, G. R. Young, A. Young)

Early generation yield trials of spring barley [PU 2(d)]

The adverse effect of mildew in a trials' field can be exceptional and disease control in one trial grown in 1987 produced an average yield increase of 27%. The presence of mildew is used to aid selection but large effects of the disease tend to obscure partial resistance. It is possible that early generation yield trials grown under such conditions reflect the presence or absence of an effective major-gene resistance to mildew rather than a realistic measure of yield potential. In 1988, therefore, instead of a series of two-replicate randomised trials without disease control, two series of single replicate squential trials with a systematic control layout were grown. One series was grown with disease control and 77, 38.5 and 38.5 kg/ha of N, P and K respectively and the other with no disease control and half the rate of fertiliser. For each series yields of the entries in each trial were adjusted according to the performance of neighbouring controls within that trial using a GENSTAT program (supplied by C. Hackett[1]). Despite similar sowing dates, the performance of entries differed considerably between the series. The overall correlation between the adjusted yields was 0.06. There was a considerable difference between the overall mean yields of the two series with a 17% reduction in the series grown with low fertiliser rates and no disease control. In the series with disease control the performance of the controls relative to the selections was much better and should provide a more accurate indicator of yield potential of the selections. Although more accurate information of yield potential may be provided by growing a series of replicated and randomised trials with disease control and a normal rate of fertiliser, growing the two different series is preferable as the contrasting information provided will lead to the selection of more stable genotypes.

(W. T. B. Thomas, G. R. Young)

Cross prediction in spring barley [PU 2(d)]

Milling energy test data were included in the 1987 cross prediction experiment to identify crosses with high probabilities of producing soft milling lines. There were more crosses with high probabilities of producing

[1]SASS

high yielding lines than soft milling lines. Some crosses had relatively low probabilities of producing lines that were either high yielding or soft milling but relatively high probabilities of combining the two characteristics. This was due to the negative correlation between the two characters in these crosses compared to the positive correlation in others. The results indicate the need to use such correlations in making joint predictions.

The technique was extended to winter barley to predict crosses likely to produce high yielding lines.

(W. T. B. Thomas, R. P. Ellis)

Barley anther culture [PU 2(d)]

The anther culture method (*Ann. Rep. 1987*, 97) was used to produce doubled haploid lines from a small number of spring and winter barley crosses. Although the winter barley crosses initially seemed more responsive to the induction medium, the frequency of green plants recovered was slightly higher in the spring crosses. There was considerable variation between crosses in their response to anther culture and the best yielded more than one green plant per spike cultured. A high proportion (40%) of the plants were diploid with a small proportion (1%) of higher ploidy levels and the rest were haploid.

(W. T. B. Thomas, G. R. Young, R. P. Ellis)

Plant development and yield in barley [PU 2(d)]

Research examining the adaptability of spring and winter barley to autumn and spring sowing was completed with a study of the relationship between leaf development and yield. Significant differences between the four genotypes studied were found for the amount of photosynthetically active radiation absorbed between sowing and anthesis. Dry weight at anthesis was similar over all cultivars but the spring cultivars Golden Promise and Maris Mink produced larger numbers of grain than the winter cultivars Video and Maris Otter. While the weight of a grain was much lower in Golden Promise the spring cultivars produced higher yields than the winter types. The efficiency of conversion of absorbed radiation into numbers of grain was higher in spring types, particularly in Golden Promise, than in the winter types.

(R. P. Ellis, G. Russell[1])

Statistical analysis of yield trials [PU 2(d)]

In 1975 SCRI initiated the use of incomplete block designs in early generation trials. In a preliminary assessment it was concluded that useful reductions of estimated plot errors had been achieved relative to complete block designs. There were, however, reservations and concern that flexibility in the number of entries tested was associated with a lower level of accuracy than could be achieved with lattice square designs.

[1]Edinburgh School of Agriculture

A more complete study, of 129 spring barley trials grown between 1980 and 1984, confirmed the greater accuracy of incomplete block designs relative to complete blocks. Data were reanalysed to determine if the use of row + column analysis could have resulted in yet further improvement. While there was considerable variation between seasons the ratio of residual error mean squares to complete block analysis was 1.70 and 2.24 for row and row + column designs respectively. Yield was affected by many factors including site, year, generation of test line, seed multiplication in New Zealand in the previous generation, and date of sowing, but not plot size. However, error variability was only affected by years, sites and plot size.

(R. P. Ellis, C. D. Kershaw[1], D. Robinson[1])

Pre-harvest selection for malting quality [PU 2(f)]

In winter barley grown in Scotland, the period between harvest and sowing may be too short to enable quality testing of the mature grain, so a technique to enable selection for quality prior to harvest is being sought. Milling energy determinations made on several cultivars, harvested and dried up to a month before maturity, gave the same ranking order as was observed for the mature grain (*Ann. Rep. 1987,* 168). Samples from a trial with commercial cultivars and breeders' lines, were tested at 4 and 6 weeks after ear emergence (growth stages 75 and 85: Zadoks, Chang & Konzak, 1974) respectively. At the earlier stage, differences between genotypes for milling energy were slight and effective selection was not possible. At the later stage, however, there were clear differences between cultivars and, based on 50 determinations, the correlation co-efficient between milling energy values 6 weeks after ear emergence and those at maturity was $r = 0.83$ ($p<0.001$). This technique has considerable promise for quality selection.

(J. S. Swanston, I. A. Cowe[2])

Trial cereal crops in collaboration with other organisations [PU 2(g)]

As a participating member of the BSPB trialling system, SCRI tested cultivars of winter wheat, winter and spring barley and oats submitted for National List year 1 and 2. Trials of winter and spring oats were grown for IGAP (Welsh Plant Breeding Station). Spring barley trials were undertaken for Plant Breeding International, Cambridge in Aberdeenshire, Fife and at Invergowrie. Spring barley and oat trials were grown for Dalgety Agriculture Ltd at Invergowrie.

The 1987/88 winter was mild and autumn sown cereals grew well, making assessment possible for disease resistance, standing ability and yield. Spring sown trials gave good information for both disease susceptibility

[1]SASS
[2]Chemistry Department

and yield and showed little sign of manganese deficiency which had caused problems in previous cereal trials at Invergowrie (*Ann. Rep. 1987*, 58). Plot drills have been modified to place fertilizer directly into the coulter during sowing, and with other husbandry improvements and occasional foliar sprays of manganese the problem appears to have been overcome.

To assess disease resistance most trials received no applications of fungicide. However, in the few trials of winter and spring barley which were sprayed there was a marked response to chemical protection. This response was largely due to the control of powdery mildew (*Erysiphe graminis*).

**Table 1. Yields of standard cultivars in sprayed and unsprayed trials of winter barley**

| | *Yield, t/ha* | | *% yield increase* |
|---|---|---|---|
| *Cultivar* | *without fungicide* | *with fungicide* | *from fungicide* |
| Gerbel | 7.12 | 8.55 | 20.1 |
| Halcyon | 7.30 | 8.84 | 21.1 |
| Igri | 6.92 | 9.65 | 39.5 |
| Panda | 6.19 | 9.37 | 51.4 |
| C.V. | 5.7 | 4.2 | |

Sprays: propiconazole + tridomorth, fenpropimorph, carbendazim + prochloraz and propiconazole, applied in November and at G.S. 31, 40, 59

**Table 2. Yields of standard cultivars in sprayed and unsprayed trials of spring barley**

| | *Yield, t/ha* | | *% yield increase* |
|---|---|---|---|
| *Cultivar* | *without fungicide* | *with fungicide* | *from fungicide* |
| Digger | 8.73 | 9.19 | 5.3 |
| Doublet | 6.82 | 8.76 | 28.4 |
| Klaxon | 6.73 | 8.88 | 31.9 |
| Natasha | 5.74 | 7.69 | 34.0 |
| Regatta | 7.34 | 9.16 | 24.8 |
| C.V. | 5.6 | 3.7 | |

Sprays: fenpropimorph and carbendazim applied at G.S. 30 and 39

These observations are in agreement with those published by SAC and NIAB.

(A. Young)

Pollen tube-mediated transformation in faba bean [PU 18(b)]

A transformation system utilising natural pollen tube growth to introduce foreign genes into ovules has the potential to be widely-applicable, simple, efficient and speedy. Minimum times between pollination and style excision which still permit seed set for faba bean cv. Troy have been determined to be 9 h at 18°C. Plasmid DNA, containing the bacterial gene coding for beta-glucuronidase (GUS) has been applied to the freshly cut

ovary surface after emasculation, pollination and style excision. The resultant seeds, when mature, will be screened for GUS activity.

(G. Ramsay, A. Kumar[1])

Faba bean cytogenetics [PU 18(b)]

A range of chromosome stocks is being developed to allow the efficient assignment of genes and RFLPs to linkage groups. The most useful aneuploids are trisomics. Of the six chromosomes in the *Vicia faba* genome, five are expected to be found as primary trisomics. The remaining chromosome is a large metacentric and may be more realistically obtained in the trisomic form as two separate tertiary trisomics, each representing one chromosome arm. An asynaptic mutant was used to generate primary trisomics. Out of five possible primary trisomics, three have now been discovered among 191 seedlings from asynaptic plants. These will be identified using chromosome banding techniques. Tertiary trisomics derived from the metacentric chromosome can be expected in the progeny of crosses between stocks carrying two translocations involving the metacentric chromosome. These crosses have been made and are currently being screened for tertiary trisomics. An alternative method of assigning genes to the metacentric chromosome is to search for linkage between the particular gene and cytological markers on the chromosome. Crosses between two divergent inbred lines differing in one major C-band on the metacentric chromosome have been made for this purpose.

(G. Ramsay)

Pod retention and raceme vascular architecture in faba bean [PU 18(b)]

Claims have been made that faba beans with an independent vascular supply (IVS) to each flower within a raceme shed fewer pods, with implications for improved crop earliness and yield stability. Seeds from eight populations reportedly containing plants exhibiting IVS characteristics were supplied by Dr P. Gates[2]. In a morphological study the numbers of major and minor vascular bundles and their branches were determined in raceme axes which had been fixed, stained and cleared. Comparisons between IVS and supposedly normal non-IVS lines failed to reveal significant differences in patterns of vascular branching. Plants exhibiting enhanced early pod set from within heterogeneous, supposedly IVS populations have now been selected for further comparisons with control plants.

(G. Ramsay)

Germplasm collection of faba bean [PU 18(b)]

A collection of faba bean accessions (cultivars, inbred lines, breeding lines, cytogenetic stocks and landraces) and wild *Vicia* species has been assembled from a variety of sources. From this collection 180 faba bean accessions and 53 wild species accessions have been rejuvenated and multiplied in insect-screened polythene tunnels and field cages.

(G. Ramsay)

[1]Tissue Culture Department
[2]University of Durham

# BRASSICA GENETICS DEPARTMENT

A. B. WILLS

The Department has investigated over a number of years, in collaboration with the Chemistry Department, the content of glucosinolate compounds in foliage and seeds of *Brassica* genotypes. Progeny analysis and biometrical techniques have been used to study inheritance and the response to selection of genes controlling synthesis of these compounds. It is worth emphasising that progress in these studies cannot be rapid, as the analytical procedures are time-consuming and a two-year generation time is normal.

Since work began in 1978, four generations of selection for both high and low levels of thiocyanate ion ($SCN^-$) in kale have been achieved. Analysis of the fourth generation showed that both selections have been highly successful; the mean $SCN^-$ content of low selection lines now being only half that of the high lines. Moreover, it can be inferred from the statistical analysis that further progress could be made by continued selection. Lines low in $SCN^-$ should provide animal forage superior to contemporary cultivars, while the availability of lines extracted from a common gene pool but with contrasting levels of $SCN^-$ content should provide valuable experimental genotypes for animal feeding studies.

An alternative approach to the study of progoitrin was afforded by confirmation that it occurs at very low levels in the foliage of the turnip cv. Hybrid Petit White. Levels of this glucosinolate and its precursor have been assessed, in crosses derived from Hybrid Petit White, both in turnip and synthesised *B. napus*. The evidence now available suggests that both compounds vary independently in turnip $F_2$ progenies, although precise genetic analyses are not yet available. A similar range of variation was not found in the synthetic *B. napus* progenies but, given the result above, might be expected to occur in their crosses to swede and rape.

The completion of these genetic studies in the two species will allow appropriate strategies to be derived for the evaluation of the possible roles for low-glucosinolate materials as improved fodders and experimental genotypes.

Breeding new cultivars of swede [PU 4(m)]

The selection WMXcacc (SS8) had the highest dry-matter yield of entries in the trials of advanced selections for a second year (see PU 4(f)). It has therefore been entered into National List Trials in 1989. Bred at SCRI

from a cross cv. Marian × (cv. Regent × cv. Broadland), made at IGAP (WPBS), it has good mildew resistance and a high dry matter yield. It has a low dry-matter content, purple skin, yellow flesh and intermediate shape. In contrast, the selection DBOxbbd (SS1) did not yield well enough in second year NIAB VarTest Trials to warrant entry into National List Trials.

The swede pedigree breeding programmes, with and without selection for clubroot resistance, reached the $F_4$ and $F_5$ generations, respectively. There is no earlier generation material in these programmes. To make further progress in improving yield, quality, disease and pest resistance for stockfeeding and for human consumption, more knowledge on the inheritance of these traits is required and new breeding methods need to be explored.

(J. E. Bradshaw, D. J. Gemmell)

Inheritance of resistance to powdery mildew in swede [PU 4(i)]

The inheritance of adult plant resistance to powdery mildew in swede was determined from a complete $F_1$ diallel set of crosses of 11 inbred lines, assessed in 1987. The most resistant lines were derived from cultivars Bangholm Dima (two lines) and Bangholm Magres (one line). Resistance was controlled by partially recessive genes and there was no evidence of maternal effects. It was concluded that the resistance is capable of controlling natural infections of powdery mildew under conditions favourable for disease development, that it can be used readily in both pedigree and hybrid breeding programmes, and that it should prove durable.

(J. E. Bradshaw, D. J. Gemmell, C. J. Williamson[1])

Sugar content of swede [PU 4(1)]

The sugar content of 19 cultivars of swede, grown in rows 50 and 75 cm apart, was determined. Sugar concentration ranged from 54.3 to 78.7 g/kg fresh-weight and was correlated with dry-matter content which ranged from 90.4 to 138.7 g/kg. The average concentration of fructose, glucose and sucrose in the dry-matter was 225.0, 328.4 and 34.5 g/kg DM, respectively. Although the total sugar content of the dry-matter was not associated with dry-matter content, the high dry-matter cultivars tended to have less fructose and more sucrose than the low dry-matter ones. Row-width had little effect on sugar content compared with the differences between cultivars.

These results confirmed that there has been little change over the last 150 years in the dry-matter and sugar contents of swedes. However, it is not clear from the literature if higher contents would improve the feeding value of swede. Studies have therefore been initiated to produce swedes with combinations of very high and very low sugar and dry-matter contents for animal performance studies.

(J. E. Bradshaw, D. W. Griffiths[2])

[1]Mycology and Bacteriology Department
[2]Chemistry Department

Turnip mosaic virus (TMV) symptoms in swedes [PU 4(k)]

To test swedes for symptoms to an IHR (Wellesbourne) isolate of TMV, seedlings were manually inoculated in a greenhouse and in nylon mesh (Tygan) covered tunnels.

Thirty-six lines at various generations of inbreeding from different cultivars, inoculated at the four leaf stage in a Tygan tunnel, were visually assessed for leaf symptoms after 10 weeks. Symptomless plants were tested by ELISA. Three inbred lines from cv. Ruta Øtofte, one inbred from cv. Magnificent and one each from the crosses of cv. Vogesa × cv. Marian and cv. Fenix × cv. Pentland Harvester were symptomless and ELISA negative.

Sixty-one families from the $F_4$ pedigree swede breeding programme were tested under glasshouse conditions. After 10 weeks only two families were symptomless and ELISA negative. All other families had symptoms varying from mild vein clearing to severe leaf curling and plant stunting.

In a second glasshouse test which included 16 further lines of swede from crosses made to a virus resistant line, all plants of one line were symptomless and ELISA negative, whereas four lines had symptomless plants, some of which were ELISA positive. The other 11 lines were segregating, susceptible plants, therefore ELISA testing was not necessary. Families of fifth generation inbreds from the cross cv. Magres × cv. Champion were also included in the test. These had been produced by selfing nine plants shown to be symptomless and ELISA negative in a previous test. Five lines were resistant but the remainder segregated susceptible plants.

Nine old cultivars of swede thought to have some resistance to TMV were also tested. All plants of the cultivars Tiperary and Doon Spartan had leaf symptoms whereas within the cultivars Calder, Crimson King, Superalative, Grandmaster, Wye, Wilhemsburger and Kiri a proportion of the plants were symptomless.

(D. J. Gemmell)

Turnip cultivars for the Scottish uplands [PU 4(m)]

A polycross breeding programme to improve yield in turnips continued. Eight lines, all yielding higher than the mean (6.94 t/ha) of the controls, were selected from the fourth generation trial in 1987. A final polycross multiplication with 16 plants from each line was made.

The transfer of clubroot resistance from an experimental line of Dutch stubble turnip to traditional type turnips was completed. A polycross multiplication was made from 9 of the resistant lines using cv. Nepe Foll as the recurrent parent. Dry matter yield was assessed for lines selected for bulb shape (*Ann. Rep. 1986,* 56) using cv. Green Top Scotch as the recurrent parent. The tankard shape had a dry matter yield of 3.47 t/ha and the globe 4.57 t/ha compared with Green Top Scotch at 4.65 t/ha. In a

glasshouse test with two clubroot populations 8768 and 8766, the disease index for the tankard multiplication was zero for each population, 12.96 and 6.67 for the globe multiplication and 87.04 and 50.0 respectively for Green Top Scotch.

The polycross multiplication of clubroot resistant lines, using cv. Green Top Yellow as the recurrent parent, was also assessed for yield. This material had a dry matter yield of 5.02 t/ha compared with 6.38 and 5.44 t/ha for Green Top Yellow and ECD04 respectively.

(D. J. Gemmell, C. J. Williamson)

Improvement of leafy brassicas [PU 4(n)]

*Rape improvement programme*

This programme continues to be broadly based with the aim of combining improvements made in yield, disease resistance, levels of the anti-metabolities S-methyl cysteine sulphoxide (SMCO) and the glucosinolates, winter hardiness and palatability. Fifty-seven new cross-combinations were produced, most of which were either backcrosses for the introgression of low levels of erucic acid and glucosinolates in the seed, or crosses between lines with good mildew or clubroot resistance or both, and high yielding lines with reduced levels of SMCO and glucosinolates.

Generations $F_2$-$F_6$ were assessed in replicated trials at Gourdie Farm. Heavy rain at sowing nullified the effects of herbicide application and in some trials there was heavy infestation of clubroot. Selections for seed production and further testing numbered 15 from $F_2$, five each from $F_3$ and $F_4$, three from $F_5$ and one from $F_6$. Selections in these generations had average dry matter yield advantages over the control cv. Emerald of 8, 16, 11, 10 and 12% respectively. The mean dry matter yield of Emerald over all the trials was 6.10 t/ha. Levels of SMCO were reduced, with one line 30% lower than the mean of the controls and improved levels of resistance to mildew and clubroot were also demonstrated. The latter must be checked to ensure that the source of major gene resistance is not lost or diminished due to methods of seed production and selection for high levels of cultivar purity.

The cultivar Bonar was added to the UK National List and is to be considered for inclusion on the NIAB Recommended List in 1989. Overwinter sheep grazing trials comparing Bonar with three other UK and two New Zealand forage rapes showed that it was the most preferred cultivar. Live weight gains on Bonar in February/March were similar to those obtained in October/November. The cultivar Arran continued to be very successful in New Zealand and is now also being sold in Australia.

A further stage of the early-generation cross-prediction project (*Ann. Rep.1987,* 62) (with Professor P. D. S. Caligari[1]) was completed. The assessment of within-plot variation showed good correlation between single plants and whole plots for weight or weight related characters but poor correlation for characters such as mildew resistance, flowering and

plant height. The amounts of variation for the characters measured differed between genotypes. Ten plants from each of the six selected 1986 populations and thirty plants from each of the thirty 1987 populations were grown-on and bag-selfed to produce seed for replicated $F_3$ trials in 1989.

Experiments using a different load cell design in the FTC texture press to measure stem hardness (*Ann. Rep. 1987*, 62) were completed. The single-blade design gave very similar results to the multi-blade design used originally and confirmed the relationship between the texture press compression/shear readings and the thickness and diameter of the ring of lignin tissue in the stem.

*Dual-purpose cropping of rape*

A three year experiment which provided two years data on both forage and seed production was completed. The mean forage dry weight yield for all harvest dates was 8.60 t/ha for the forage rape cv. Hobson and 7.60 t/ha for the oilseed rape cv. Jet Neuf. The equivalent mean seed yield at 9% moisture was 1.8 t/ha for Hobson and 2.2 t/ha for Jet Neuf with oil contents of 40.8 and 39.7% respectively. Over the period of the experiment dry matter forage yields in commerce for rape were in the range 4.5-5.5 t/ha and seed yields 2.5-3.1 t/ha with oil contents of 41-43%. No significant differences were found between the two cultivars for SMCO and total glucosinolate content in the vegetative tissue.

(W. H. Macfarlane Smith)

*Anti-nutritional factors in rape breeding*

Glucosinolates are present in all parts of the rape plant and the dangers to animal health from excessive intake of forage rape have been recognised. However in the breeding of oilseed rape, no consideration was given to the risks to wild or domesticated animals which might feed on the vegetative part of the plant.

The glucosinolate content of two cultivars each of oilseed rape (cv. Bienvenu — single low and cv. Ariana — double low) and forage rape (cv. Hobson and cv. Bonar — low progoitrin) were recorded overwinter. Samples of vegetative tissue were taken at regular intervals over the period October-March and analysed for total glucosinolate content.

No relationship was found between total glucosinolate content in the vegetative tissue and that in the seed used to sow the experiment. The values of the former did not vary consistently from cultivar to cultivar, although levels rose from about 2 to >30 $\mu$ mol/g during the sampling period.

SMCO levels were similar for Bonar, Hobson and Bienvenu and increased steadily from 0.29 to 0.69 g/100 g over the sampling period. Ariana initially had similar or slightly lower levels of SMCO but increased rapidly after December to levels which remained consistently higher (0.70-0.78 g/100 g) for the rest of the sampling period.

(W. H. Macfarlane Smith, D. W. Griffiths[2], B. Boag[3])

[1]Department of Agricultural Botany, University of Reading
[2]Chemistry Department
[3]Zoology Department

*Selection for high and low thiocyanate ion content in kale*

Kale leaves have a relatively high content of the indole glucosinolates which, on hydrolysis by the enzyme myrosinase, release the goitrogenic thiocyanate ion ($SCN^-$). However, it is not known if all the effects of the thiocyanate ion are undesirable.

Therefore in 1978 studies were initiated to examine direct and correlated responses to selection for high and low contents of $SCN^-$. Sub-populations were established by half-sib family selection from the third generation of the kale polycross improvement programme. In 1988, after four generations, their mean contents were 193.7 and 102.3 mg $SCN^-$/100 g DM respectively. The mean contents of the two sets of families selected from these sub-populations to continue the programme were 233.0 and 83.1 mg $SCN^-$/100 g DM respectively. Continued progress is expected as the heritabilities in the two sub-populations were 0.43 and 0.42 respectively, and these were only slightly less than the heritability of 0.50 in the original population. The correlated responses to selection, including the effects on non-indole glucosinolates, are being analysed.

(J. E. Bradshaw, D. W. Griffiths[1])

Stock multiplication [PU 4(f)]

Seed crops of 38 breeding lines of rape, swede, kale and turnip ranging from $F_3$ to advanced generations were produced in insect proof polythene tunnels. Seed yields showed a small decrease (Table 1) on the previous season. Incomplete vernalisation in some rape lines and poor establishment and root development in some rape, swede and turnip lines were observed. The former resulted from the mild winter and late sowing and the latter from cultivation and drainage problems.

Incidence of disease was generally low and no clubroot was observed. Aphid (*Myzus persicae*) infestation proved difficult to control, particularly during flowering when blow-flies were introduced to the tunnels to promote pollination. After flowering, nicotine fumigation controlled infestations but as nicotine is difficult to use in this situation alternative treatments are being sought.

Strict screening of breeding lines was undertaken to eliminate residual variation and to ensure uniformity of advanced selections. Of 30 rape lines raised for multiplication in 1988, 13 required further selection to meet the official uniformity standard. As reported (*Ann. Rep. 1987*, 63) certain forage lines, which have *Brassica rapa* ssp. *nipposinica* in their pedigrees, display wide, continuous variation, the genetical basis of which is not yet fully understood.

In addition to breeding lines, multiplications were made of a further 24 obsolete swede cultivars in the SCRI collection and one obsolete turnip cultivar. Additionally, *B. rapa* var. yellow sarson and six kale cultivars which cannot be obtained commercially were multiplied.

[1]Chemistry Department

All seed stocks produced in 1988 have attained the required germination standard after testing according to ISTA rules.

Plots of advanced swede and kale lines were established in the field for assessment of distinctness, uniformity and stability under conditions close to those of official DUS testing.

(J. N. Dick)

**Table 1. Seed yield**

| | 1988 | 1987 | 1986 | 1985 |
|---|---|---|---|---|
| | *mean yield g/m²* | | | |
| Swede | 115 | 147 | 98 | 100 |
| Rape | 98 | 114 | 112 | 118 |
| Kale | 94 | 84 | 62 | 76 |
| Turnip | 96 | — | — | — |
| | *mean yield g/plant* | | | |
| Swede | 96 | 103 | 55 | 77 |
| Rape | 38 | 42 | 35 | 43 |
| Kale | 45 | 36 | 32 | 33 |
| Turnip | 39 | — | — | — |

*Growth regulator response*

Previous work (*Ann. Rep. 1987*, 64) reported potential benefits from the use of the growth regulator, triapenthenol, in seed production of forage rape. The regulator increased total seed yield and the number of seeds per pod, decreased the 100 seed weight and plant height and exhibited a degree of fungicidal activity.

However, plants subsequently grown in the same polythene tunnel showed unfavourable responses to chemical residues in the soil. Plants were smaller and had slightly lower total seed yields compared with plants grown in a tunnel not previously treated.

Further assessment of residual effects of triapenthenol in the soil will be made.

(J. N. Dick, W. H. Macfarlane Smith)

*Trials of advanced selections*

Assessment of breeder's advanced selections of swede, kale and forage rape was carried out in 16 trials at seven sites throughout Scotland. Crop emergence was erratic and slow at most locations as June was very dry. This encouraged attacks by first generation cabbage root fly (*Delia radicum*) despite the use of insecticide sprays. Selection SS8 demonstrated tolerance to *D. radicum*, both in numbers of surviving plants and final yield, in comparison to control cultivars of swede which were heavily infested (Table 2). In 12 trials over two years, SS8 has produced significantly higher fresh and dry weight yields than all other entries, including control cultivars.

**Table 2. Swede: means from five sites**

| *Control cultivar* | *Fresh yield (t/ha)* | *Dry matter %* | *Dry matter yield (t/ha)* |
|---|---|---|---|
| Angela | 108.60 | 10.38 | 11.27 |
| Bangholm Magres | 90.44 | 11.87 | 10.78 |
| Marian | 99.46 | 10.83 | 10.76 |
| Melfort | 84.41 | 13.08 | 11.09 |
| Ruta Øtofte | 96.21 | 11.41 | 10.98 |
| *Control cultivar mean* | 95.82 | 11.51 | 10.98 |
| *Breeding selection* | | | |
| SS8 | 112.54 | 10.52 | 11.85 |
| GDLaaa | 90.33 | 12.73 | 11.51 |
| GRGaaa | 87.33 | 12.10 | 10.55 |
| GRLaga | 81.83 | 13.09 | 10.77 |
| M4M2a-c | 92.30 | 11.31 | 10.45 |
| NMM3a-d | 98.93 | 11.02 | 10.90 |
| RN55 ga | 90.42 | 11.41 | 10.31 |
| *Selection mean* | 93.38 | 11.74 | 10.91 |
| *Grand mean* | 94.60 | 11.63 | 10.95 |

**Table 3. Rape: means from five sites**

| *Control cultivar* | *Fresh yield (t/ha)* | *Dry matter %* | *Dry matter yield (t/ha)* |
|---|---|---|---|
| Emerald | 64.60 | 12.12 | 7.79 |
| Hobson | 64.52 | 12.27 | 7.92 |
| Caron | 55.24 | 12.20 | 6.72 |
| Bonar | 75.88 | 10.52 | 7.96 |
| *Control cultivar mean* | 65.06 | 11.73 | 7.60 |
| *Breeding selection* | | | |
| SR8 | 66.84 | 11.98 | 8.01 |
| SR7 | 59.54 | 11.46 | 6.80 |
| 78017/1 | 60.16 | 12.25 | 7.37 |
| 81100/2 | 55.19 | 13.43 | 7.39 |
| *Selection mean* | 60.43 | 12.28 | 7.39 |
| *Grand mean* | 62.75 | 12.03 | 7.48 |

Two kale trials, one irrigated, were grown at Gourdie Farm. May and June had little rain and the irrigated trial established significantly better than the non-irrigated trial. Rainfall was normal over the remainder of the growing season. At harvest the mean dry weight yield of the irrigated trial was 9% better ($P<.001$) than that of the non-irrigated trial. Kale selection SK4 finished its second year in trial and had a 13% higher dry weight yield

than the mean of the four control cultivars Bittern, Canson, Condor and Kestrel over this period. SK4 also showed similar yield advantages over other SCRI selections and control cultivars at sites in New Zealand and France.

Forage rape was grown at five sites, with one overwintered at an elevation of 150 m to assess winter hardiness. Selection SR8 produced high dry weight yields in November and overwintered well, maintaining yield and crop quality (Table 3). Although weather conditions in 1988 were similar to those in 1987 the four control cultivars, which were grown in both years, gave a 26% higher fresh weight yield in 1988, evidence of the sensitivity of forage rape to environmental variation.

(R. N. Wilson)

Synthesis of artificial Brassica napus [PU 4(g)]

Synthesis of *B. napus* from its parental species (*B. campestris* and *B. oleracea*) using embryo or ovary culture (*Ann. Rep. 1987*, 67) can now be used routinely to introduce characters and continue broadening the genetic base available to the breeder.

In 1986 synthetic *B. napus* plants were produced by intercrossing *B. campestris* cv. Hybrid Petit White, which contains only trace amounts of 2 hydroxy but-3-enyl glucosinolate (progoitrin), with a marrowstem kale inbred (*Ann. Rep. 1986*, 60). HPLC analysis of the leaf and root glucosinolate content of progeny plants from these synthetics showed that they lacked progoitrin and contained only small amounts of its precursor. One progeny was used in intercrosses with swede breeding lines.

(J. R. T. Hodgkin, J. Middlefell Williams, D. W. Griffiths[1])

Production of new Brassica material through tissue culture [PU 4(h)]

*Anther culture in swede*

The anther culture protocol tested previously (*Ann. Rep. 1987*, 66) was used to produce homozygous plants from three heterotic swede $F_1$ hybrids, namely cv. Marian × cv. Criffel (MC), cv. Bangholm Wilby × cv. Criffel (BC) and cv. Bangholm Magres × cv. Criffel (BMCR).

Donor plants of good health status yielded 13.9 embryos per 1000 anthers. Microspore viability and stage of maturity in anthers sampled from each plant were assessed daily. Viability ranged from 11 to 86% (mean 50.2%) and maturity from uninucleate to the start of the second nuclear division. However, neither character was correlated with final embryo yield per plant or per day. Over 90% of the embryos obtained came from anthers incubated for a short initial high temperature period (24 h, 35°C) rather than the standard 48 h, 35°C treatment. There were marked differences in yield between the three lines, the hybrid BC giving only 2 embryos from 2940 anthers while MC and BMCR gave 20.9 and 16.4 per

[1]Chemistry Department

1000 anthers respectively. The poor response of these lines, as compared with those tested in 1987, is at least in part due to genetic factors and anther culture protocols may have to be varied according to the genotype used.

(J. Middlefell Williams, J. R. T. Hodgkin)

*Selection for herbicide resistance* in vitro

Brassicas offer particular opportunities for the development of *in vitro* selection procedures and resistance to herbicides was chosen as a desirable character for study in the development of appropriate protocols. For *in vitro* selection callus and meristem cultures of the cultivars *B. campestris, B. oleracea* and *B. napus* cultivars and of several inbred lines were established. Investigation of the susceptibility of germinating seedlings of the genotypes showed that all were killed by 0.5 mM glyphosate and 50-100 nM chlorsulphuron.

(M. Ramsay, J. R. T. Hodgkin)

Genetics studies Brassica campestris and Brassica napus [PU 4(i)]

The characterisation of morphological and isoenzyme markers in *B. campestris* and determination of their expression in synthetic *B. napus* continued. Variation was detected in esterase isoenzymes of *B. campestris* previously thought to be invariant. A minimum of three loci are needed to explain the observed variation and pollinations to establish its inheritance were made. The demand for stocks containing marker genes for experiments on *in vitro* selection and genetic transformation is increasing and pollinations were made to produce *B. campestris* stocks with the largest possible number of morphological and isoenzyme markers.

Resistance to *Plasmodiophora brassicae* (clubroot disease) in *B. campestris* is considered to be controlled by three major dominant genes. Three lines of the ECD *B. campestris* tester set (ECD01, ECD02, ECD03), supposedly homozygous for different pairs of these major genes, and the universal susceptible tester cv. Granaat (ECD05) have been used to develop inbred lines for each gene. Tests on selfed progenies of the tester lines with the highly pathogenic populations derived from Pb 8025 (supplied by P. Mattusch[1]) and maintained on ECD01 revealed segregation for resistance to this population in two progenies. It appears that additional resistance genes were present in the original tester lines and therefore crosses were made for further genetic studies.

Analysis of glucosinolate content and type in the leaves and roots of the progeny of crosses derived from the *B. campestris* cv. Hybrid Petit White suggest that inheritance of the reduced production of progoitrin is not under control of a single gene and that complex interactions between the progoitrin content and that of its precursor glucosinolate (but-3-enyl) occur in the $F_1$ and $F_2$ progenies.

(J. R. T. Hodgkin, C. J. Williamson[2], D. W. Griffiths[3])

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Self-incompatibility in Brassicas [PU 4(j)]

Pollen germination inhibitors detected in self-pollinated stigmas of *B. oleracea* have characteristics in common with phytoalexins produced following an incompatible host-pathogen interaction in plants. Very small quantities of pollen germination inhibitors are produced in stigmas and it has not yet been possible to collect sufficient tissue for their identification. Phytoalexins are known to be produced in response to a number of abiotic elicitors such as UV light and experiments were therefore conducted to determine the effect of UV light on pollen germination and on the production of phytoalexins or pollen germination inhibitors in incubated pollen. *B. oleracea* pollen germination was markedly inhibited by 15 min exposure to u.v. light and, such tubes as were produced were short, contorted and contained large amounts of callose — characteristics of incompatible pollen. Bulk collections of pollen have been made for analysis by thin layer chromatography and pollen bioassay techniques.

Self-incompatible lines of *B. napus*, derived from crosses between *B. oleracea* and *B. campestris* lines homozygous for different S-alleles, were test-crossed to determine the activity of three *B. oleracea* S-alleles (S23, S14 and S2) and two of *B. campestris* (designated Sa and Sb) in synthetic *B. napus*. The results showed that both *B. oleracea* and *B. campestris* alleles could be active in *B. napus* and that a variety of inter-locus dominance interactions, similar to interallelic dominance interactions present in the parental species, occurred. One *B. napus* line was self-compatible as a result of loss of incompatibility function in the stigma although pollen incompatibility specificities were found to be unimpaired when it was used in crosses with lines sharing a common active S-allele.

The *B. napus* lines were intercrossed to generate progenies heterozygous at both S-loci (i.e. containing four different S-alleles) and these showed complex dominance relationships between alleles, differing in pollen and pistil. In some cases it appeared that only one of the four alleles was expressed in these heterozygotes. Isoelectric focussing was carried out on stigma extracts for protein bands associated with particular S-allele homozygotes and species were identified. The relationship of these protein bands to particular S-alleles will be tested in $F_2$ progenies. Preliminary evidence indicates that at least part of the self-compatibility detected in the synthetic *B. napus* line was associated with the particular combination of *B. campestris* and *B. oleracea* S-alleles involved. Such a phenomenon would allow $F^1$ hybrid oilseed rape cultivars, which are self-compatible, to be produced from self-incompatible parents.

(J. R. T. Hodgkin, S. C. Dharmaratne[1])

[1]Research Student

# POTATO GENETICS

G. R. MACKAY

Planting at The Murrays Farm and at Blythbank was completed expeditiously under good conditions this season, and finished about a week earlier than usual. The warm dry spell that followed through May and into June led to early emergence and at Blythbank, where the moisture retention properties of the organic soil aided good establishment, there was rapid canopy development. However, the mineral soil at The Murrays rapidly went into moisture deficit, and the plants became stressed and canopy development was poor. This was exacerbated by inadequate weed control, attributed to failure of the herbicide in the dry conditions that existed pre-emergence. After the rain in July weed growth was such that it was necessary to resort to hand pulling in some plots. Yields were low and the quality of the tubers generally poor, making selection difficult; particularly in the earlier generation where data on disease resistance, cooking and crisping qualities etc. are lacking. In these instances selection has to be largely based on yield performance, general appearance and absence of defects of the produce of rather small albeit replicated plots of many hundreds of clones. This serves to underline the need to continue to research and develop the means to apply selection pressure more efficiently amongst the early generations of potato breeding programmes when most genetic variation is still present in the populations under selection.

The production of cultivars has now been identified as too near-market to continue to attract support from the public domain and arrangements are being made via the Dalgety/Nickersons Consortium to ensure that the products of our research development do reach the market place. In consultation with technical representatives of the Consortium four clones were identified as worthy of submission to National List Trials. Two clones, 13121AB2 and 12721AE14 have been positively identified as having good potential for export as well as performing well in the UK. The former did particularly well in a series of trials on three organic farms and two SCRI sites (The Murrays, East Lothian and Yonderton, Ayr) where it proved the highest yielding entry at all five sites, significantly outyielding the maincrop control cv. Désirée. Two other submissions, 14069A4 and 14032A8, are primarily seen to be for UK ware production. The former is a double PCN resister (to both *Globodera rostochiensis* and *G. pallida*), and has similar low temperature sugar stable characteristics to 13737 1 and is therefore of interest to the processors (for crisping). The latter is a high

yielding white skinned good quality second early/early maincrop with $H_1$ resistance to *G. rostochiensis* and a superior spectrum of resistance to common pathogens to cv. Maris Piper.

Season 1988 was the last at The Murrays and Pentlandfield following the final transfer of staff to Invergowrie in August. There was an excellent seed crop at Blythbank and it is probable that it will be necessary to continue maintenance of our high grade seed stocks at the site for the foreseeable future.

The decision to close Pentlandfield by March 31 1989 had immediate repercussions on the planned winter work programme, which had to be substantially curtailed. Much credit must be accorded to the staff at Pentlandfield in that routine data collection was completed by Christmas, enabling selections to be made. Organising and distributing seed for 1989 at Blythbank was undertaken in the New Year, freeing staff to transfer equipment and materials to temporary accommodation at Mylnefield by March. Clearly the transfer has caused something of a hiatus in the ongoing research programme and much data has been set aside in abeyance until the transfer is complete.

Low temperature sugar stability in stored tubers [PU 1(a)]

The identification of a small but fairly consistent proportion of clones which, after storage at 4°C, give superior (paler coloured) crisps to those of cv. Record has now become a routine feature of the cooking/crisping quality tests, carried out on all clones entering the fourth year ($M_2$) of evaluation. From 280 clones in the 1988 $M_2$ fry tests identified 34 clones with superior low temperature sugar stability to that of cv. Record, of which 25 have been selected for further assessment in 1989.

A small replicated trial of low temperature sugar stable variants was grown at The Murrays. Preliminary analysis of the fry colour data suggests that they are similar in this character to the clone 13737 1, submitted to National List Trials (NLT) in 1987 and now in its second and final year. The trial also confirmed that 14069A4, submitted to NLT this year, is also capable of producing pale fry colour products (= low reducing sugars) after 4°C storage.

Preliminary analyses of the fry colour data from the seedling tuber progenies (*Ann. Rep. 1987*, 72) have been completed. From all three fry test dates there were significant differences in fry colour between the progeny means and the ranking of the means was consistent with the phenotypes of the parental clones, indicative of an additive heritable component of variation. Further analyses of these data are being undertaken. The Chemistry Department completed analyses of sucrose, glucose and fructose levels of the freeze dried samples (see Report p.150). Initial analyses of these data are consistent with the documented

relationships between sugar concentrations and fry colour. However, there is evidence of substantial variation within progenies for their fry colours and sugars and in some instances these fall outside the range of their parents. If the performance of field-grown clonal material confirms the data from the glasshouse raised seedling progenies then it may be possible to select clones with further improved low temperature sugar stability. To examine this and to provide additional data on the genetic architecture of this trait, seed tubers of the seedling progenies were retained and planted in a randomised trial at Blythbank. Each progeny was represented by up to 48 individual clones, planted as four randomised replicate plots of 12 single plants.

At harvest each surviving single plant was hand dug; three tubers of each clone were retained as a seed stock and two taken for storage, one at 4°C and the other at 10°C. Tubers from 1243 clones will be replanted as three plant plots in 1989. The stored tubers were subsequently fry tested and the fry colour data collected for analysis. Freeze dried samples of the tubers have been stored for analysis of sugars by the Chemistry Department.

Coincident with these studies collaborators within SCRI and at ESCA are studying the underlying biochemistry of this phenomenon in a few advanced clones, including 13737 1. The study on 13737 1, funded by an Increased Flexibility Scheme grant from DAFS, has demonstrated significant differences in amylolitic enzyme activity between 13737 1 and the cultivars. Record and Pentland Dell. Whether this is a causal effect or a consequence of other changes in sugar and starch synthesis/degradation in the potato is being investigated.

(G. R. Mackay, F. Ritchie)

Seed multiplication and maintenance [PU 1(a)]

Planting at Blythbank was completed expeditiously in the last week of April. Emergence and establishment were good and the seed crop did not suffer the check in growth caused by the early season (May/June) drought as did the ware crop at The Murrays. Despite a cool wet summer bulking up was rapid and it was necessary to defoliate in early August to keep tubers to an acceptable size.

The incidence of virus infection and blackleg was low. Yield and tuber numbers were higher than average, as was the general quality of the seed. A favourable spell of weather coincident with harvest in September also assisted in ensuring a very clean seed sample going into store.

All advanced clones and cultivars submitted for inspection were passed and granted approved stock status.

(G. R. Mackay, I. M. Chapman)

Overseas trials of advanced clones [PU 1(b)]

All clones which reached their sixth clonal year of assessment ($M_4$) in 1987 were trialled to assess their export potential at sites in Spain (Valencia and Rioja), Cyprus and Israel. The inclusion of those clones which had previously performed well raised the total to more than 60 at each site. Clones G7707 2, 13121AB2 and 12721AE14 again demonstrated exceptional yield potential and the late blight resistance of 13121AB2 was particularly noted at Valencia where, due to unusual weather, a severe blight epidemic occurred. Clone 13121AB2 seems particularly well adapted to more extreme environments where its resistance and tolerance to foliar diseases such as late blight and *Alternaria* are contributive factors in its high yield potential. Clone 12721AE14 is earlier maturing and does not have the same level of resistance to disease but its undoubted capacity to bulk early and produce an attractive parti-coloured (red splashed) tuber support the view that it could find a niche in those markets, such as the Canary Islands, formerly dominated by cv. King Edward or more recently by cv. Cara. G7707 2 will be entered for approved stock inspection in 1989 with a view to its submission to NLT in Autumn that year.

As a consequence of the Barnes review the trialling of advanced clones overseas as potential cultivars will cease in 1989 unless industry funding is found to support it. However, the more strategic element associated with our research into resistance and tolerance to *Verticillium* and *Alternaria,* and their interaction with saline irrigation water has been recognised and will continue. In 1989 collaborative studies will concentrate on *Alternaria* and its interaction with saline irrigation water on a limited sample of clones and cultivars. These clones and cultivars have been selected because their previous performance in the more routine trials has identified them as having a range of resistance and tolerance to *Alternaria,* as well as a range of maturities. By examining symptom expression and bulking rates in the presence of saline and non-saline irrigation water these experiments will provide a clearer insight into the mechanism of tolerance and its relationship to resistance and maturity. The trials are being undertaken by our collaborators at Gilat, Israel.

A number of less advanced clones identified as having export potential have been retained and a few have been sent for trial in 1989 at two sites in Portugal, courtesy of the Scottish Seed Potato Development Council. 13121AB2 and 12721AE14 were requested for on-farm trials by the kibbutzim in Israel and have been supplied for this purpose courtesy of Chamberlain Fieldfare Ltd.

(G. R. Mackay)

Resistance screening and enhancement of resistant germ plasm [PU 1(a)(e)]

*Virus diseases*

A full range of screening tests for virus disease resistance (*Ann. Rep 1987,* 81) was carried out, except that the trial for response to potato mop top virus was discontinued.

Work on the production of parental clones multiplex for major genes conferring resistance to potato viruses Y and X (PVY and PVX) continued (*Ann. Rep. 1987,* 82). In progeny tests, one parent clone appeared to be triplex or quadruplex for its PVX resistance gene, with no susceptible segregants in its progeny. Experimental progenies, produced by selfing five cultivars susceptible to PVY, were also tested to evaluate the suitability of the cultivars for use as susceptible parents in test clones. The results await analysis.

The effectiveness of two potato clones (10341 ab 19 and 10527 ab 20) as infectors in potato leafroll virus (PLRV) exposure trials has been compared over a number of years. The two clones have been grown in separate replicated blocks and the numbers of exposed receptor plants subsequently infected in the different blocks have been compared. The blocks with 10341 ab 19 as infector developed slightly more infections than those with 10527 ab 20 as infector. Although both clones are susceptible and tolerant, comparison of the PLRV titre in the leaf sap of infected stocks indicated that the one which gave rise to more infections in the field trials had a slightly higher titre than the other ($p = 0.05$). This is consistent with the suggestion that low PLRV titre is likely to make a clone a poor source of virus for transmission by aphids (*Ann. Rep. 1987,* 187).

(R. M. Solomon, G. R. Mackay, J. S. Muir)

Resistance screening [PU 1(e)]

*Fungal and bacterial diseases*

Thirty-eight clones and cultivars were screened for resistance to powdery scab (*Spongospora subterranea*) in the joint SCRI/NSCA trial near Portsoy, Banff. The trial experienced severe disease pressure, and only one genotype (G8743 AC 15) showed a similar level of resistance to the highly resistant cv. Ulster Lancer. In plots planted with seed tubers of different physiological age comparison of disease levels on tubers indicated the youngest of the three ages of seed produced the highest proportion of diseased tubers. This was perhaps because the latter part of the summer, when tuberisation would have occurred, was wetter.

The powdery scab trial in artificially infested soil beds was repeated with the same progenies as the previous year (*Ann. Rep. 1987,* 83). Good agreement was obtained with previous results, despite the soil having been replaced and inoculated with peelings from a new source of infected tubers.

Tests continue to be carried out for detecting resistance/susceptibility to skin spot (*Polyscytalum pustulans*). In the 1988 test, 14 of 59 genotypes examined were at least as resistant as the resistant control cv. Arran Consul, scoring 6 on a 1-9 scale of increasing resistance.

Research on resistance to gangrene (*Phoma foveata*) has resulted in the development of a test suitable for use on tubers produced by glasshouse-grown seedlings. There was a good correlation ($r = 0.80$) between the results of the test on 80 glasshouse-grown seedlings from each of twelve progenies and those obtained previously on field-grown tubers of the same progenies. The test is a rapid means of acquiring information on the inheritance of gangrene resistance, and identifying progenies with useful levels of resistance.

Desprouted seed tubers of 38 genotypes were vacuum-infiltrated or jet-injected with *Erwinia carotovora* subsp. *atroseptica* the day before planting at Pentlandfield in May. Both methods of inoculation depressed the mean overall yield by 10%. The most sensitive cultivars were Maris Bard and Pentland Javelin (>30% yield loss) and the least sensitive were Stormont Enterprise, Croft and Cara. Despite the pronounced effect on yield, there was a general lack of above-ground symptoms of blackleg. Stem blackleg was observed in all three replicates of clone G8743 AC 15 and occasionally in the cultivars Ulster Sceptre, Wilja and Désirée. Two clones which suffered as great a yield loss as G8743 AC 15 showed no stem symptoms. No yield loss was recorded in the new cultivar Brodick.

The development of a glasshouse test for resistance to *Alternaria solani* continued (*Ann. Rep. 1987*, 83). The 14 clones and cultivars assessed in 1987 were tested in the glasshouse for a second year to confirm the validity of the assessment. The results agreed well with the previous year's field and glasshouse results ($r = 0.87$ and $r = 0.93$, $P<0.001$, respectively). A progeny test for resistance to *A. solani* was also developed, using true seedlings of progenies from crosses between resistant, intermediate and susceptible parents. Seedlings inoculated 8, 9 or 10 weeks after sowing developed a satisfactory level of infection and susceptibility appeared to increase with seedling age.

As *A. solani* does not sporulate readily in culture, media and lighting and temperature regimes were compared to find a reliable method of producing spores for screening tests. Prolific sporulation was achieved using V8 agar at pH7 and incubating the cultures in continuous fluorescent light at 22°C for 2 days and subsequently in darkness at 10°C for a minimum of 4 days.

*Late blight*

In 1986 crosses were made between clones and cultivars resistant, intermediate or susceptible to late blight in the foliage and/or the tuber, to determine whether tuber and foliage resistance are related.

Thirty-one progenies and the 10 parents of these crosses were assessed for foliage resistance in a field trial at Yonderton Farm, Ayrshire, and in tuber blight tests in the laboratory. There was a low but significant correlation between foliage and tuber resistance ($r = 0.48$, $P<0.05$).

Resistance in the foliage was correlated with the mean resistance of the parents of each progeny ($r = 0.71$, $P<0.001$), but tuber resistance was not.

One hundred and fifty eight breeders' selections were also assessed in the field trial at Yonderton, and the cv. Brodick showed resistance superior to that of the resistant control cv. Cara. Two hundred and fifty-two fifth year selections and 111 progenies were screened in the glasshouse for both foliage and tuber resistance. For the progenies there was a correlation of 0.56 ($P<0.001$) between the two scores.

To quantify the value of blight resistance, the cultivars Teena, Shelagh, Torridon, Brodick and two clones, all of which have been highly resistant to late blight in field tests in Scotland, were trialled on two organic farms in Wales and one in Somerset. The cultivars Wilja and Désirée were included as susceptible controls. Only the resistant cultivars gave an increased yield at the first site where blight appeared but the small yield differences at the other sites, where little blight developed or harvests were late, could not be attributed to blight resistance. Clone 13121 AB 2, a blight resistant submission undergoing National List testing, was the highest yielding clone at all three sites.

(R.L. Wastie, H. E. Stewart)

Dihaploid potatoes [PU 1(c)(d)]

Eighty-six dihaploids from virus resistant tetraploids were screened for resistance to PVX and PVY. Nine were resistant to both diseases, 29 were resistant to PVX alone, and 40 to PVY alone. Test crosses are being carried out to determine the genotypes of resistant clones to identify those duplex for major resistance genes from which quadruplex tetraploids can be produced for use in 4x × 4x crosses.

Seven elite dihaploids have been chromosome doubled this year by regenerating plants from callus obtained from leaf discs. Test crosses have been carried out with three chromosome-doubled dihaploids using cultivars as pollen parents. The variance of the character tuber yield within progenies derived from such crosses was significantly less than that within control progenies derived by intercrossing heterozygous tetraploids in the seedling year. The control progenies were taken from the top, middle and bottom thirds of those progenies used in the cultivar breeding scheme in 1986 and ranked by overall preference score. There was no significant difference between the variances of the two progeny groups however for tuber yield in the first clonal year. The percentage of clones selected on yield and tuber appearance from the test progenies was over twice the percentage selected from the controls (7.8 and 3.2% respectively).

Second generation dihaploids were obtained from two chromosome-doubled dihaploids and three of these have been chromosome doubled once again to regain the 4x level and to further increase homozygosity. No reduction in female fertility was observed in the second compared with the

first generation of dihaploids. An average of 2.8 seeds per pollination were produced by the first generation cv. Pentland Crown dihaploid, PDH40, when pollinated by the cultivars Maris Piper or Désirée whereas 3.0 seeds per pollination were produced by PDH777, a dihaploid obtained from chromosome-doubled PDH40, with the same pollen parents.

Two dihaploids have been found which are moderately male fertile in dihaploid × dihaploid crosses. Both were derived from tetraploids obtained from crosses between blight resistant dihaploids and PCN resistant tetraploids. One (PDH638) has combined resistance to late blight and PCN and the other (PDH727) has resistance to PCN (*G. pallida*) with blight resistance yet to be confirmed.

Tetraploids were produced by pollinating two dihaploids, which have high resistance to foliage blight and PCN (*G. pallida*), with cultivars utilising the capacity of the dihaploids to produce unreduced (2x) female gametes. The resistances within these tetraploid offspring were assessed. Although the two dihaploids had similar levels of resistance and similar origins there were significant differences in their parental values. Seventy-three per cent of the offspring of PDH551 scored 6 or more on a 1-9 scale for blight resistance compared with 47% of the offspring of PDH625. Of these highly blight resistant clones, 41% of the offspring of PDH551 also had high levels of PCN resistance (i.e.<25% of the number of cysts found on Pentland Crown controls) compared with 7% of PDH625 offspring. The transfer of both resistances together from dihaploids to their 4x offspring was therefore less efficient than the transfer of blight resistance alone from blight resistant dihaploids (23 to 96% resistant offspring) or PCN resistance alone from PCN resistant dihaploids (15 to 65%).

(M. J. De, Maine)

# SOFT FRUIT GENETICS

D. L. JENNINGS

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For the first time we report progress from germplasm manipulation both by traditional methods of hybridisation and by molecular transfer: progress from traditional hybridisation methods has given two new red raspberry cultivars, Glen Lyon and Glen Garry, the new black currant Ben Tirran and promising selections in all the soft fruit species being studied, while progress from molecular transfer has demonstrated for the first time how *Agrobacterium* species can be used to incorporate exogenous DNA into *Rubus* germplasm. Research into the genetic potential of new germplasm has again emphasised the value of *Ribes* genotypes from northern latitudes for improving the expression of frost tolerance and of asiatic *Rubus* species for improving the expression of disease resistance. Study of the host-pathogen interaction between black currant and *Botrytis cinerea* has provided a remarkable insight into the cause of the 'running-off' disorder.

Provide improved cultivars of raspberry and study relevant characters [PU 3(a)]

Following further promising results for selection 7515C5 in regional trials both the Scottish NFT Panel and the Brogdale NFT Panel recommended that it should be released as a new cultivar. The selection ripens in mid-season and is noted both for its easily managed growth habit and its good fruit quality. Hence it is a suitable alternative to cv. Glen Clova. The Scottish Panel also recommended the release of 7518E6, which in 1987 and 1988 also gave promising results in regional trials in England and Scotland. Although the selection has gene $\underline{L}_1$, which confers large fruit size and is sometimes unstable, the Panel recommended it because of its considerable merits and its characteristic large stipule. The large stipule, which is also conferred by gene $\underline{L}_1$, provides a means of avoiding the instability problem because it allows vegetative material to be screened for trueness to type. The selection 7133R40, which also has gene $\underline{L}_1$ but has not shown instability, was recommended for commercial appraisal by the Brogdale Panel, but the Scottish Panel considered that it was too late for Scottish conditions.

*Resistance to fungal pathogens*

The segregation of resistance to cane botrytis (*Botrytis cinerea*) was studied in five progenies derived from *Rubus pileatus*. Three of the progenies were from crosses in which highly susceptible parents were crossed either with a

resistant $F_1$ hybrid or with one of two resistant second-backcross hybrids. The other two were from crosses where both parents were resistant, being second backcross hybrids in one instance and an $F_1$ and a first backcross hybrid in the other. Although there were significant differences between the mean resistances of these five progenies, the differences were small and each progeny contained a high proportion of resistant genotypes, thus emphasising the dominant nature of the genes for resistance. The previous report (*Ann. Rep. 1987,* 88) commented that resistance had been transferred from *R. pileatus* to raspberry with little or no diminution over four generations, but because there was no discontinuity of resistance levels, the evidence was unequivocal for the segregation of a major gene. Some evidence of such discontinuity was obtained in 1988. The frequency distribution for the resistance levels of 152 pubescent segregants differed significantly from the expectation for a single normal distribution and was a good fit to the expectation for a mixture of two normal distributions with equal variance. The more susceptible of the two distributions contained only 15% of the segregants, however, and the distribution for 81 non-pubescent segregates was a good fit to a normal distribution. It was concluded that the occurrence of major-gene segregation for resistance was not proved, but that much of the evidence was consistent with such a hypothesis.

Further evidence was obtained for the hypothesis that the resistance to *Leptosphaeria coniothyrium* shown by *R. pileatus* and its $F_1$ hybrids with raspberry was largely conferred by their hard, non-raspberry-like growth which cannot be readily transferred to commercial raspberry cultivars.

The previous report (*Ann. Rep. 1987,* 88) also commented on the high resistance to fruit botrytis shown by the selections 7936F5 and 7815B8. In tests on 15 samples in 1988, the lowest incidence of mouldy fruit on the third day after harvest was shown by 836F7 and 836F9, which are hybrids of 7936F5. Samples of 7936F5 were not available for this series of tests, but the breeding line appears to have shown the most consistent resistance of all the materials tested over several seasons.

(D. L. Jennings, R. J. McNicol, E. Brydon)

Agrobacterium spp. as vectors of DNA [PU 3(a-d)]

Various media and sources of explant from red raspberry, blackberry and red raspberry × blackberry hybrids were assessed to find a reliable regeneration system from vegetative tissues. Regenerants were produced from leaf discs, but only when the discs were orientated with their adaxial surface uppermost. Adventitious shoots were produced from peeled and unpeeled internodal stem segments, but not from their epidermal peelings. The genotypes differed considerably in their ability to regenerate and the type and concentration of hormones, sucrose, the presence of light and the absence of activated charcoal were all crucial for success.

The binary vector system of *A. tumefaciens* was used to inoculate leaf discs and internodal stem segments with strain LBA4404, which contains either the binary vector PBI 121.X, with the beta-glucuronidase (GUS) marker gene, or Bin 19, which has the neomycin phosphotransferase II (NPTII) gene. Kanamycin sulphate, which is the selective agent for the latter, inhibited organogenesis at 50 mg/l, the concentration normally used for selection in other plant spp., and was therefore unsuitable for use with this material. However, all the regenerants obtained from material inoculated with the vector carrying the GUS marker gene were successfully assayed by the fluorogenic assay procedure. Seven GUS positive plantlets were identified which confirmed that the marker gene had been transferred.

(R. J. McNicol, J. Graham)

Provide improved cultivars of black currant and study relevant characters [PU 3(b)]

SCRI P9/8/7 was recommended by the NFT Panel for commercial release as cv. Ben Tirran. Its late flowering and ripening characteristics provide a valuable extension to the cropping season. The provisional recommendation to release F6/3/39 (*Ann. Rep. 1987,* 90) was withdrawn because of poor results in jamming tests.

Seedlings P17/1/23 and P17/1/27, which had previously shown promise, yielded poorly in 1988 due to lack of vigour and insufficient regrowth. Of the selections in advanced trials at Brogdale, the most promising were P10/18/116 (cv. Ben Sarek × cv. Ben Lomond), a non-processing type with early ripening and resistance to leaf-curling midge, P9/1/3, a hybrid of cv. Ben Lomond with good processing quality and early ripening, and C2/2/1, a hybrid of SCRI 243/7 with high fruit quality.

Three new seedlings were sent to Brogdale in winter 1988/89; two, incorporating the Swedish Ri 74020-16, are hybrids resulting from regular germplasm exchanges and co-operative work between the Balsgård Division of Fruit Breeding and SCRI.

*Improving plant habit*

Selections combining erect habit, improved branch strength and high productivity (*Ann. Rep. 1986,* 87) showed considerable promise in plantations in their first year of cropping. Progenies of C2/1/62 (a complex black currant × red currant hybrid) and cv. Ben More had a particularly good combination of branch strength and flexibility, which should aid mechanical harvesting and reduce management costs.

*Fruit quality*

Approximately 500 genotypes were assessed for juice colour and ascorbic acid content. The highest total pigment concentrations ($E_{515}$ at pH1) were

obtained from hybrids of P10/9/13 ([cv. Anger von Oeffelt × cv. Ojebyn) × cv. Ben Nevis] × 243/7). Three of the hybrids had higher pigment concentrations than 243/7, which has hitherto been our best source of juice quality. Other high quality genotypes include several cv. Ben Lomond × (cv. Sunderbyn II × 243/7) hybrids. These results show the value of 243/7 and its hybrids for improving quality.

(R. M. Brennan)

*Resistance to gall mite*

To facilitate identification of genotypes resistant to gall mite (*Cecidophyopsis ribis*), a preliminary study was made to assess the potential of metabolic profiling as a biochemical screen. Genotypes from the IHR (East Malling) programme with resistance derived from *Ribes grossularia* were compared with susceptible genotypes. The procedure involved low temperature solvent extraction of bud terpenoids and analysis of the extract by gas chromatography. Comparisons of chromatograms obtained for resistant and susceptible groups by Principal Components Analysis suggested that two compounds, ß-pinene and $\triangle^3$-carene, had the most significant influence on resistance.

(R. M. Brennan, G. W. Robertson[1])

*Frost tolerance at flowering*

The tolerance of simulated frost by flowering potted plants of 25 black currant genotypes was assessed. The SCRI cultivars Ben Tirran and Ben Alder showed good tolerance during flowering but less at grape stage, in contrast to the majority of genotypes examined, whose tolerance decreased as flowering progressed. The environmental conditions prior to testing were crucial. Some genotypes lost hardiness very rapidly as a result of high temperatures while others took considerably longer.

The Russian cultivars Golubka, Serezyanka, Rus and Narjadnaja were badly damaged by frost at each flowering stage, whereas the cultivars Novinka and Pilot Mamkin retained a high level of tolerance even at late stages of flowering. In cut-shoot tests several Russian cultivars, including the cultivars Nachodka, Partizanka and Dymka, showed moderately high levels of frost tolerance throughout flowering. Subject to confirmation of these results in whole plant tests, the potential of these genotypes as donors of increased frost tolerance is therefore high. Some of these genotypes are also useful sources of resistance to major pests and diseases. Scandinavian genotypes were also assessed for frost tolerance. Although the cultivars Brodtorp, Ojebyn and Ri III-10 showed fairly high levels of hardiness, with Ojebyn remaining hardy until after first open flower, other Scandinavian genotypes suffered considerable damage at full flower.

(R. M. Brennan)

[1]Chemistry Department

*Resistance of stems to* Botrytis

Pot plants of 19 black currant cultivars were wound-inoculated with three isolates of *B. cinerea,* derived from both *Ribes* and *Rubus* sources, at the end of July. Assessments of infection in August showed that isolate 434, from *Rubus,* was the most aggressive.

The most resistant genotypes, which had only occasional and limited vascular damage, were Ojebyn, Ben Tirran, P10/18/121, Ben Alder and Narjadnaja. The latter two cultivars were also highly resistant in 1987 (*Ann. Rep. 1987,* 93). The most susceptible genotypes showing large vascular lesions and associated death of the stems above the point of inoculation, were the Russian cultivars Rus, Minaj Smyrev and Golubka, and P17/1/23.

(R. M. Brennan, B. Williamson[1])

*Premature fruit drop*

Studies on the role of *Botrytis cinerea* in premature fruit drop, or 'running-off' were continued. Inoculation of flowers resulted in high levels of drop (>90%), but 74020-6 and cv. Brodtorp showed degrees of tolerance (c. 80 and 70% respectively).

Black currants were found to respond to low levels of ethylene by shedding their flowers until c. 2 weeks after anthesis, when the fruits started to swell. Flowers were found to produce a burst of ethylene about 5 days after inoculation with *B. cinerea.* No differences were found in the ability of *B. cinerea* to infect the flowers of diverse genotypes but there were considerable differences in the responsiveness of these genotypes to a range of ethylene concentrations: Baldwin shed all its flowers at low level concentrations (1.5 ppm), while 74020-6 shed only a few flowers with relatively large concentrations (6 ppm). This accords with the relative proneness of these two genotypes to 'running-off' in field situations. The evidence supports the previous conclusion that *B. cinerea* is a major contributory cause of 'running-off', and suggests that it may be possible to screen for non-proneness to the disorder by exposing flowers to ethylene.

(R. J. McNicol)

Provide improved cultivars of blackberries and other Rubus fruit [PU 3(c)]

The tetraploid, spine-free blackberry cv. Loch Ness, named in 1987, cropped well and gave good quality fruit. Considerable promise was also shown by selection 82417A12, which gave a high yield of larger fruit slightly later in the season. Only a few early ripening segregants of tetraploid blackberries occurred in progenies where a recombination for rapid ripening and early flowering had been expected to give a higher incidence of early-ripening selections. These are being used in further crosses.

[1]Mycology and Bacteriology Department

In progenies raised to transfer gene $Sf_1$ from spine-free Loganberry to Tayberry types, a small number of plants produced fruit of good quality and several selections were made. The most notable spine-free selections of hexaploid material were made from early-fruiting progenies derived from crosses between cultivars Bedford Giant or Silvan and selections carrying gene *Sf*. As in 1987 (*Ann. Rep. 1987*, 93), the deleterious effects of non-hardiness and poor fertility previously associated with this gene were not evident.

Inconsistent segregation was again a feature of the study of the inheritance of spinelessness derived from a spine-free mutant of cv. Willamette. Several possible causes of the inconsistency were eliminated, and it appeared that the segregation was influenced by the presence of the recessive gene *s*, another gene for spinelessness. A possible explanation of the segregation observed is that the spinelessness of the mutant is conferred by a single dominant gene which has pleiotropic effects on seed development similar to those known for gene *s*, and that the two genes interact to influence the success of seed development and hence the survival of the alternative genotypes.

(D. L. Jennings, R. J. McNicol, E. Brydon)

Identify strawberry genotypes adapted to the Scottish environment [PU 3(d)]

Large fruit samples, each of c. 1 tonne, from farm plots of the strawberry selection 71WC64 were appraised for their agronomic and processing qualities by several processors. Favourable comments have been obtained from canners and gateaux manufacturers. Yoghurt manufacturers have yet to report. The fruit of this selection are mostly in the small to medium size range, are exceptionally easy to husk and, because of their good red colour, process well without the addition of artificial dyes. This last quality is of major importance because of the increasing demand for 'natural' products and the anticipated ban of some artificial colouring agents.

(R. J. McNicol)

Evaluate novel fruits and rectify shortcomings by breeding [PU 3(e)]

Vaccinium *genetics*

The first progenies produced as part of the HDC-funded novel bush fruits project were raised for field planting. Further crosses were made using germplasm introduced from the USDA, Beltsville and the University of Minnesota, USA. The main objectives include improved fruit quality and resistance to *Godronia cassandrae*.

(R. M. Brennan)

## NEW BLACK CURRANT CULTIVAR

## BEN TIRRAN

The Institute and DAFS have applied for Plant Breeders' Rights for a new black currant cultivar, Ben Tirran, bred at SCRI. A stock is being propagated for commercial release in 1989.

| | |
|---|---|
| *Breeder's Number* | P9/8/7 |
| *Parentage* | cv. Ben Lomond × [(cv. Seabrooks Black × cv. Amos Black) × (cv. Seabrooks Black × *Ribesia* sp.)] |
| *Flowering* | c. 1 week later than Ben Lomond |
| *Cropping Season* | c. 3-7 days later than Ben Lomond |
| *Productivity* | Yields are similar to cv. Ben Alder and usually slightly below Ben Lomond but consistently and substantially above cv. Baldwin. |
| *Growth Habit* | Reasonably upright with good vigour and ease of mechanical harvesting. |
| *Fruit Quality* | Similar to Ben Lomond and suitable for all processing requirements. Post-harvest deterioration of fruit is less than that of Ben Alder in some areas. |
| *Disease and Pest Resistance* | Mildew resistant, but susceptible to gall mite and leaf curling midge. |

## NEW PURPLE RASPBERRY CULTIVAR

## GLENCOE

The Institute has released a new purple raspberry, Glencoe, bred at SCRI. Plants for commercial planting will be available from autumn 1989.

| | |
|---|---|
| *Breeder's Number* | 53-14-6 |
| *Origin* | A black raspberry derivative of cv. Munger into which gene *s* had been introduced from red raspberry by backcrossing, crossed with the red raspberry cv. Glen Prosen. |
| *Canes* | Vigorous, semi-erect and spine-free shoots produced in moderate numbers. Floricanes, deep purple with a conspicuous waxy bloom. |
| *Fruiting Laterals* | Medium length and stiff. |
| *Fruit* | Medium size, typically 3 gm, intense flavour, very firm, round-conical in shape and dull purple in colour. Easy to pick. |
| *Season of Ripening* | Mid season |
| *Yield* | Comparable to the red raspberry cv. Glen Clova in southern parts of the UK. |
| *Diseases & Pests* | No exceptional susceptibilities have been identified. Resistant to Verticillium wilt disease. |
| *Use* | Jam, juice, yoghurt and various flavourings. |
| *Mode of Propagation* | By root cuttings, leaf-bud cuttings, rooted stem tips or tissue culture. |

# TISSUE CULTURE

W. POWELL

The Tissue Culture Department's research activities may be considered under three general headings: (1) cell and tissue culture in plant breeding, (2) transfer and expression of genes and (3) the use of molecular and biochemical markers in crop genetics. The importance of these areas to modern plant genetic manipulation procedures is reflected in the increased level of financial support obtained from both core and external grant awarding bodies.

Considerable time has been devoted to staff training and the department now employs a range of cellular and recombinant DNA techniques. Significant research achievements include the regeneration of tetraploid and dihaploid potato plants from protoplasts and the transformation of potato, flax and a range of *Brassica* species with Ti plasmid based vectors. These technologies provide a vital link between whole plant and recombinant DNA biology. Stable tissue culture regeneration systems have also been established for *Ribes* and certain novel bush fruits.

The establishment of an active molecular biology laboratory has allowed molecular marker systems to be applied to potato, *Vicia faba*, barley and *Rubus* species. The methodology required to isolate and clone genes has also been developed and is being used to clone UsnRNA gene families from potato and maize. An understanding of the organisation of this class of gene families at the molecular level is vital to our studies on gene expression in plants.

Iso-electric focussing (IEF) is a powerful electrophoretic technique used to separate proteins. A cytogenetics/IEF laboratory has been established with the dual function of developing and exploiting protein markers in association with isogenic and aneuploid genetic stocks. An important aspect of this work is to look for linkage between proteins and characters of economic and scientific importance e.g. chromosomal location of genes involved in the tolerance of barley to salt stress and the search for genetic markers linked to these genes.

This report describes work on the integration of molecular and biochemical markers with doubled haploid production systems in barley. The approach provides new information on the stability and segregation of alleles in microspore-derived barley progeny. Doubled haploids represent fixed inbred lines and will facilitate the development of detailed linkage maps.

The Department's links with Institutes of Higher Education are of particular relevance and importance to our research philosophy. Twelve post-graduate students now pursue research projects in association with the department. This reflects both the quality and relevance of our basic research to colleagues in universities and polytechnics. Collaborative research projects with Dr J. W. S. Brown of the University of Dundee continue to flourish and receive support from the AFRC in the form of a linked research grant to examine the splicing of pre-mRNAs in plants and a research grant to examine the genome organisation of plant UsnRNA gene families. In addition, DAFS Increased Flexibility grants have been awarded to study Ac transposition in potato and to evaluate UsnRNA based transformation vectors for the delivery of antisense RNAs to plant cell nuclei.

Development of stable single cell isolation and regeneration systems [PU 19(a)]

*Barley anther culture*

In studies on carbohydrate composition and concentration on barley anther culture response it was shown that carbohydrate source can have a dramatic effect. Maltose, an ∝ 1-4 linked glucose disaccharide, has a large beneficial effect. Substitution of sucrose, the standard carbohydrate source, by maltose, resulted in an increase from 2-8 to 116 green plants being produced per 100 cultured anthers for the cultivar Tweed. The maltose-based medium also encouraged a higher proportion of embryogenic structures to develop from the barley microspores. However, significant genotypic differences in anther culture response were detected.

These results have important implications for the use of doubled haploid technology in barley breeding. The availability of large numbers of doubled haploids will not only facilitate the production of improved cultivars, but will also allow the exploitation of the barley microspore in biotechnology. The success of future research strategies based on the barley microspore will depend on the genetic stability of microspore-derived plants.

To monitor the stability of such lines biochemical markers (e.g. isozymes) have been used. A sample of 120 microspore-derived lines from the spring barley cultivar Tweed were examined for the following isozyme systems: esterase, ß amylase, glucophosphate isomerase and ∝ amylase. Genetic loci coding for these isozymes are located on 6 of the 7 barley chromosomes and therefore provide a preliminary indication of the stability of the barley genome. No major variation in banding patterns were observed for esterase, glucophosphate isomerase or ∝ amylase. Major variation was detected for ß amylase in two independent colchicine doubled haploids. Subsequent analysis of these two genotypes failed to detect further mutants. Very little genetic variability was detected in this sample of microspore-derived lines.

(S. J. Finnie[1], B. P. Forster, W. Powell)

[1]Research Student

*Genetical analysis of barley microspore derived lines*

An anther culture system based on maltose as the carbohydrate source has been applied to the following $F_1$ hybrids: cv. Blenheim × TS264, cv. Blenheim × E224 and their reciprocal crosses. Over 50 microspore-derived lines have been regenerated from each cross and will be used to assess the potential role of anther culture technology in barley breeding. The parents used to generate this population of plants have been characterised for polymorphism in isozyme banding patterns. To date polymorphism has been detected for: ∝ amylase-1 on chromosome 6I, ß amylase on chromosome 4I and a leaf esterase on chromosome 3I. The segregation of alleles at these isozyme loci in the microspore derived population has been examined. A significant deviation from the expected 1:1 ratio was observed for alleles at the ∝ amylase-1 and ß amylase loci, with an excess of Blenheim phenotypes. Blenheim is known to be more responsive to anther culture than the other parents tested and the distorted segregation ratios may reflect the preferential survival of Blenheim gametes in culture.

A series of cloned DNA probes have been used to assess the level of polymorphism between Blenheim, TS264 and E224. To date the nitrate reductase, B and C hordein and the flax ribosomal probe have been shown to detect polymorphism. These molecular markers will be used to monitor the segregation of alleles at RFLP loci in the barley microspore-derived progeny.

(D. M. Cawston, B. P. Forster, W. Powell)

Ribes *and novel bush fruits*

A wide range of *Ribes* cultivars and species have been established using shoot tip *in vitro* cultures. Methods of regeneration utilising axillary buds and internodal sections have also been investigated. As well as modern cultivars, the collection includes parental breeding stocks and cultivars and species from Scandinavia and the USSR possessing resistance genes to reversion. To complement this approach, and to increase the potential of the germplasm collection, methods for the *in vitro* storage of *Ribes* germplasm have also been developed. The cultures were maintained at 6°C under low lighting regimes on either reduced concentrations of nutrients or on novel support systems.

*In vitro* cultures of *Hippophae rhamnoides* and *Rosa canina* have been established successfully. Investigations into optimising culture conditions are in progress as is the induction of multiple apices from the roots of *Hippophae*. This species is of particular relevance not only as an alternative fruit but also for its nitrogen-fixation and soil amelioration characteristics.

(S. Millam, R. Brennan[1])

[1]Soft Fruit Genetics Department

*Development of plant regeneration procedures in crop plants*

The availability of efficient plant regeneration systems from explant tissues such as leaf and tuber discs and from stem cuttings are essential for developing *Agrobacterium*-mediated transformation and *in vitro* mutant isolation programmes. Plant regeneration procedures using leaf and tuber discs for 25 potato tetraploid cultivars and 10 dihaploid lines have now been developed. Presently stem cuttings are being used to develop plant regeneration systems for several potato lines. Plant regeneration has also been achieved from hypocotyl tissues of flax and leaf discs of tomato and *Nicotiana clevelandii*.

(A. Kumar)

*Genotypic response to a range of culture conditions in potato*

A precise and easily monitored method of *in vitro* tuberisation has been developed in potato. The method has wide applicability for producing microtubers in wild species, dihaploids and tetraploids. The ability to control tuber induction has provided a unique system for the study of the complex biochemical and physiological changes which occur during tuber initiation.

An investigation into genotype-dependent tissue culture response has also been undertaken using the cultivars, Cara and Pentland Crown, and a range of their dihaploids. Their responsiveness using four tissue culture methods, namely, *in vitro* multiplication, microtuberisation, adventitious regeneration and protoplast culturability has been evaluated. A better understanding of the genetics of tissue culture response will allow the development of effective screening systems to identify responsive cultivars for *in vitro* genetic manipulations.

(M. C. Coleman, W. Powell)

Exploitation of protoplasts and microspore systems in crop improvements [PU 19(b)]

*Potato somatic hybridisation*

Studies exploiting somatic hybridisation to combine precisely two dihaploid genomes for the resynthesis of tetraploid potato genotypes have been undertaken. A prerequisite for fusion is regeneration of plants from the parental protoplasts and therefore a number of potato dihaploid lines (PDH) have been assessed for their amenability for protoplast culture and regeneration. Protoplast yields from 4-6 week old shoot culture leaf material were: $1 \times 10^6$ protoplasts/g fresh weight for PDH 40, 51, 417, 505 and 727, 0.5-1 $\times 10^6$ protoplasts/g fresh weight for PDH 638, 700, 724 and 135.

PDH 40, 51 and 417 reformed a cell wall after 3-4 days and had 10-15% plating efficiency after 10 days. Ten to 15% of the PDH 40 and PDH 51

colonies regenerated shoots 4 months after initial protoplast culture. These two totipotent dihaploid lines have been fused with protoplasts of non or poorly dividing lines for somatic hybridisation experiments.

The majority of the dihaploid fusion partners have no distinctive morphological characteristics which would allow putative somatic hybrids to be identified. To overcome this problem diagnostic isozyme (esterase) and RFLP profiles of the dihaploids have been determined. The co-dominant expression of these markers will allow us to identify potato somatic hybrids unequivocally.

(S. Cooper-Bland, W. Powell)

Introduction of foreign genes into plants [PU 19(d)]

Two transformation procedures have been developed. Firstly, *Agrobacterium*-mediated transformation has been successfully developed for several plant species including potato (cultivars Désirée, Pentland Squire and Wilja and the dihaploid lines PDH 505 and 51), *Nicotiana tabacum, N. clevelandii,* flax (*Linum usitatissimum* L.) and faba beans (*Vicia faba*). The transformation experiments with these plants were performed using either *tumefaciens* strains (*A. tumefaciens* C58 strain :: pGV 3850 or *A. tumefaciens* LBA 4404 strain :: pBin 19) or *A. rhizogenes* LBA 9202 :: pBin 19. These genetically engineered *Agrobacterium* strains contain either the neomycin phosphotransferase II gene (NPT II) conferring resistance to kanamycin alone or NPT II in combination with the hygromycin phosphotransferase gene (HPT) (also conferring resistance to hygromycin) or chlororamphenicol acetyltransferases gene (CAT) (also conferring resistance to chlororamphenicol) as a selectable marker. Initially, putative transformants were selected on the basis of their ability to grow in the presence of either kanmycin (150 $\mu$g/ml), hygromycin (30$\mu$g/ml) or chlororamphenicol (30 $\mu$g/ml). The kanamycin and chlororamphenicol resistant plants were further characterised by NPT II dot-blot and CAT assays respectively, and shown to be positive. Secondly, protoplast mediated transformation has been developed for tobacco protoplasts using polyethylene glycol (PEG) and electroporation methods. Transient expression of CAT and ß-glucuronidase (GUS) genes has been demonstrated. Presently, several types of chimaeric genes, either of viral or plant origin, are being introduced into protoplasts to study their expression.

(A. Kumar)

Brassica

*In vitro* stocks of *Brassica* accessions have been established in culture. These include *B. napus* (two rapid-cycling and two marker lines) rapid cycling *B. oleracea* and three *B. campestris* (two marker and one triozine-resistant lines).

This working stock is used for experiments on transformation, induction of flowering and research into pollen and microspore culture.

The response of each *Brassica* accession has been extensively tested for their reaction to a range of antibiotics prior to their incorporation into a defined transformation system. Also, research into assessing the optimum time of transfer of regenerating shoots to kanamycin for maximum selection efficiency has been performed.

A major thrust of this research programme is in the use of rapid-cycling types of Brassicas to enhance the basic efficiency of the system and to enable selection and confirmation (both by molecular and inheritance studies) to be achieved in a significantly shorter period. Enhancing the *in vitro* flowering process will allow applications of pollen and microspore assessment to be interfaced with conventional transformation technology. Putative transformants of three named cultivars, four rapid-cycling accessions and one breeding line have been obtained.

(S. Millam)

Study the inheritance, stability and copy number of gene inserts in transgenic plants [PU 19(f)]

*Production of potato leafroll virus (PLRV) resistant transgenic plants*

PLRV is responsible for significant economic losses in the potato crop worldwide. Attempts have been made to produce PLRV resistant transgenic potato and *Nicotiana clevelandii* plants. An approach based on the introduction of a c-DNA clone of the coat protein gene of PLRV by a binary plant expression vector system (*A. tumefaciens* strain LBA 4404 :: pBin 19) has been made.

(A. Kumar, M. Mayo[1], B. Reavy[1])

*Pre-mRNA splicing in plants*

The majority of genes transcribed by RNA polymerase II contain intron sequences. These sequences also appear in the primary transcript and must be removed before the mRNA can be translated into protein. Removal of introns from pre-mRNSs is known as splicing and is important as a fundamental aspect of gene expression. A series of expression plasmids containing monocot, dicot and hybrid introns have been constructed to analyse splicing following introduction into plant protoplasts by chemical (PEG) or electroporation methods and into dicot plants by agroinfection.

(A. Kumar, J. W. S. Brown[2], C. Simpson[2])

Study genome organisation and structure at the nucleic acid level [PU 19(g)]

*Potato*

Genomic and c-DNA libraries of *Solanum tuberosum* cv. Désirée have been constructed in pUC18. Over 100 clones from the c-DNA library have

[1]Virology Department
[2]University of Dundee

been selected on the basis of size (>0.5 kb) and copy number, for use as probes. Thirty cultivated tetraploid potatoes have been screened with a selection of c-DNA probes to determine the level of polymorphism after digesting their total genomic DNA with four restriction enzymes (EcoRI, EcoRV, BamHI and HindIII). The level of polymorphism detected was extremely high and one probe enzyme combination (pSTc34 × EcoRI) was capable of discriminating between the majority of the potato cultivars examined. In addition to anonymous cDNA clones, clones of known function are also being included in the analysis. Selected tetraploid crosses (Désirée × cv. Pentland Crown and Désirée × cv. Cara) have been examined for the segregation of RFLP markers. A set of well characterised dihaploid lines extracted from Pentland Crown and Cara are also being screened for the inheritance of RFLP markers. Correlation between a given molecular profile and an agronomic or disease resistance character may indicate that the two characters are genetically linked. The chloroplast DNA of European tetraploid cultivars has been examined for polymorphism. The chloroplast DNA restriction patterns of Maris Piper, Croft, Shelagh, Stormont Enterprise and Estima differ from the majority of the cultivars examined. Maris Piper, which traces through its maternal lineage to the nematode resistant CPC accession 1673 and the Neo-tuberosum derived clone Shelagh share a common cytoplasm. A knowledge of the cytoplasmic constitution of potato genotypes will assist in the analysis and interpretation of reciprocal differences.

(R. Waugh, N. Duncan, W. Powell)

*Barley*

cDNA libraries of *Hordeum vulgare* cv. Prisma have been constructed in plasmid vector pUC18 and a range of clones selected for inclusion in a RFLP programme. In addition, a range of known genomic and cDNA probes have been obtained. These include ß hordein, ß amylase, nitrate reductase and chalcone synthase from barley and ribosomal DNA probes from wheat and flax. To construct a genetic linkage map two barley crosses have been identified for study. The first is a cross between the spring barley cv. Prisma and a mildew resistant *spontaneum* (HS28) selection. Ten restriction enzymes have been used to digest the DNA of the two parents and polymorphic probe/enzyme combinations are being used to screen the $F_2$ and backcross generations. The second cross is between cv. Tweed and the multiple marker stock cv. Brandon. Doubled haploids produced by the *H. bulbosum* technique have been extracted from the $F_1$ hybrid of Tweed × Brandon and will provide the segregating population for the RFLP linkage map.

(K. J. Chalmers[1], C. Murray[1], R. Waugh, W. Powell)

[1]Research Student

Vicia faba

A c-DNA library of *V. faba* has been constructed in pUC18 and a range of clones assembled and grouped into 3 size categories (0.5-0.7 kb, 0.7-1.2 kb and >1.2 kb). These probes have been used to screen 20 *V. faba* genotypes. Compared to barley and potato the level of polymorphism detected in the *Vicia* populations sampled is small. However, probe/enzyme combinations have been identified which detect polymorphism. Furthermore, intra-population variability is also detectable. DNA has been isolated from trisomic lines (2n = 2x + 1 = 13) and used to chromosomally locate polymorphic probes. For the segregation analysis, two genetically diverse genotypes (Optica and 172) have been hybridised to produce the $F_1$, $F_2$ and backcross generations.

(W. T. G. van de Ven[1], G. Ramsay[2], R. Waugh, W. Powell)

Rubus *species*

The variability in chloroplast DNA type of 20 *Rubus* genotypes was examined by southern hybridisation. DNA extracted from the *Rubus* accessions was digested with two restriction enzymes (EcoRI and EcoRV) and heterologous chloroplast DNA sequences from barley and pea were used as probes to detect *Rubus* chloroplast DNA sequences on southern blots of *Rubus* total DNA. Considerable interspecific chloroplast diversity was detected in the *Rubus* genus. However the chloroplast DNA within the red raspberry and hybrid berry cultivars were found to be uniform.

Cladistic principles based on the parsimony assumption have been used to generate a phylogenetic tree of the *Rubus* genus based on data obtained from the chloroplast DNA analysis. The phylogenetic tree grouped the taxonomically defined species and is in agreement with data based on morphological criteria. However, the Japanese red raspberry *R. illecebrosus* which is classified in the *Idaeobatus* sub-genus has diverged considerably in terms of evolutionary time from other species within this sub-genus. *R. illecebrosus* is very distinct morphologically and the molecular data provides a quantitative estimate of the relationship between species that is difficult to obtain from morphological data.

(R. Waugh, M. S. Phillips[3], W. T. G. van de Ven[1], W. Powell)

*Analysis of plant UsnRNA gene families in potato and maize*

U-type small nuclear RNA molecules are present in the nucleus of every eukaryotic cell where, combined with a specific group of proteins they form characteristic particles known as UsnRNPs or 'SNURPS' (small nuclear U-type ribonucleoprotein particles). A range of different 'SNURPS' are responsible for the excision of introns from pre-mRNAs and re-ligation of the

[1]Research Student
[2]Cereal and Legume Genetics Department
[3]Zoology Department

exons prior to mature mRNA export into the cytoplasm for translation (a process known as splicing). An understanding of UsnRNA gene structure, organisation and expression in plant cells is therefore fundamental to an understanding of the process of splicing itself.

Using a cloned U2 snRNA gene from *Arabidopsis* as probe, we have screened a EMBL3 potato genomic library and a EMBL4 maize genome library for homologous sequences. Thirty-one first screening potato positives and 200 first screening maize positives were identified. Eight potato and seven maize clones have been positively identified to third screening level. Three potato clones Pot U2.4, Pot U2.22 and Pot U2.11 and one maize clone Mz U2.27 have been mapped by restriction mapping and subcloned on to plasmid vectors. The DNA sequence of each of these four clones has been determined and compared to that of the *Arabidopsis* U2 snRNA genes. Whilst highly homologous, each clone has several different nucleotide changes indicating the presence of variant UsnRNA populations in potato and maize. We are currently performing transient expression analysis of individual U2 clones and screening potato and maize genomic libraries for U1 and U5 snRNA genes.

(R. Waugh, J. W. S. Brown[1])

Construction of detailed genetic linkage maps using molecular (RFLPs) and isozyme markers [PU 19(h)]

*Isoelectric focusing (IEF)*

IEF is a powerful technique used to separate proteins in acrylamide gels. The superior resolution over continuous electrophoresis systems allows the detection of proteins present at low concentrations as well as those in abundance. Since proteins are the end products of gene expression the analysis of protein banding patterns in IEF gels can be used to study the genes themselves. Some proteins are of importance in their own right and others are of interest for use in varietal identification and genetic studies such as gene mapping and gene linkage.

The technique facilitates the detection of polymorphism, and the assays are usually non-destructive, the embryo is not required and can be grown on after analysis. Parallel work is being carried out in potato which shows a high degree of polymorphism.

The polymorphism detected in barley and potato have been investigated further, and, using appropriate genetic stocks the genes coding for certain proteins have been located to specific chromosomes. In barley the intra-chromosomal mapping of isozyme loci has also been performed.

(B. P. Forster, R. Waugh)

[1]University of Dundee

Develop and utilise suitable aneuploid stocks for use in genetic linkage studies [PU 19 (j)]

*Aneuploid stocks*

The Department maintains and researches a comprehensive collection of genetic stocks of barley, wheat, rye, *Agropyron, Aegilops,* potato and tomato. These include various aneuploid stocks, lines carrying more chromosomes or less chromosomes than the normal euploid complement (used to locate genes to specific chromosomes), translocation and telosomic lines (important in assigning genes to specific chromosome arms) and recombinant and isogenic lines (used in intra-chromosomal gene mapping).

(B. P. Forster, E. Baird)

*The genetic control of salt tolerance*

This work aims to identify genes in the barley genome which influence tolerance to salt and to locate the most potent alleles of these genes in wild barley populations. The wheat/*Hordeum vulgare* and wheat/*H. chilense* disomic chromosome addition lines have been used to determine which Hordeum (barley) chromosomes carry genes for tolerance to salt. The addition lines were grown in hydroculture containing 0, 175 and 200molm$^{-3}$ NaCl. The data for various growth and yield parameters showed that the addition of barley chromosome 5 (5I of *H. vulgare* and 5H$^{ch}$ of *H. chilense*) markedly improved the tolerance of wheat to salt stress indicating that homoeologous group 5 chromosomes carry genes for tolerance to salt. Work is now underway in collaboration with Professor E. Nevo (University of Haifa, Israel) to test the salt tolerance of over 20 populations of wild barley (*H. spontaneum*) collected from various diverse habitats in Israel.

(B. P. Forster, W. Powell)

Gene isolation by insertional mutagenesis [PU 19(1)]

*Isolation of useful genes by 'transposon tagging'*

A research programme to isolate useful genes of 'transposon tagging' using the transposable elements Ac/Ds of maize has been initiated. Ac/Ds has been cloned into co-intergrative plant expression vectors (*Agrobacterium tumefaciens* strain C58 :: pGV 3850, provided by Professor P. Starlinger of Köln University) in order to introduce these elements into the genome of crop plants. Transgenic potato plants (Désirée and Pentland Squire) have been produced using these *Agrobacterium* strains. Molecular biological techniques are being employed to confirm the presence of Ac/Ds and to investigate their frequency of transposition. Furthermore, transformation experiments have been performed to introduce the Ac/Ds elements into a dihaploid line, PDH 505, possessing the potato cyst nematode resistance gene $H_1$ in the heterozygous condition.

A 'transposon tagging' programme has also been initiated in flax (*Linum usitatissimum*). The introduction of the Ac/Ds elements into the genome of flax and their relatively high frequency of transposition have been successfully demonstrated. Presently, attempts are being made to identify transgenic plants having insertion mutations affecting nitrate reductase activity.

(A. Kumar, P. Whitty, M. Roberts[1], J. Draper[1])

[1]University of Leicester

# MYCOLOGY AND BACTERIOLOGY DEPARTMENT

D. A. PERRY

The main objective of the Department is to understand the processes underlying the interactions between host and pathogen in a range of diseases of economic importance. Reactions occur at the genetic and the biochemical level and an understanding of the reasons for differences between the successful establishment of an infection and the failure of disease to develop is particularly important for the development of improved disease control strategies.

Protoplasts formed from sporangia of different isolates of *Phytophthora infestans* have been induced to fuse by electrofusion and colonies regenerated from the products. The method promises to provide new insights into the inheritance of mating type and virulence patterns in this fungus. The pathogenicity of *Erwinia carotovora* subsp. *atroseptica* to potatoes is dependent on pectate lyase production which is temperature controlled through an effect on genes encoding for enzyme production. Oligosaccharides released from potato cell walls by pectate lyase have been shown for the first time to be capable of eliciting phytoalexins and their activity depends on the number of uronic acid residues. A resistant response of barley to mildew infection similar to that involving phytoalexins was demonstrated when extracts of yeast cells were applied to leaves prior to inoculation.

Serological studies on *Erwinia carotovora* have shown that it is difficult to distinguish between the subspecies *carotovora* and *atroseptica*, and improvements in both selectivity and sensitivity are being sought. Serological methods have also been used to quantify mycelium of *Phytophthora infestans* in potatoes and an antiserum was raised to spore balls of *Spongospora subterranea*.

The *Phytophthora* spp. isolated from outbreaks of raspberry root rot are being characterised by electrophoresis of whole protein contents and it has been shown that the pathogenic *P. megasperma* isolates involved are similar regardless of their geographic origin and are distinct from the closely related *P. fragariae*. Variation in susceptibility to root rot has been demonstrated in inoculation tests offering a hope that resistance can be incorporated into breeding lines. Progress has been made in understanding the epidemiology of downy mildew of *Rubus* species.

The soil microbiology group have been developing accurate methods to quantify nitrogen transformations which occur in the proximity of plant roots and the principal organisms involved.

Hot water treatment of seed potato tubers [PU 13(a)]

The results of a field experiment using seed of the cultivars Désirée and Estima subjected to differing time × temperature hot water treatments (HWT) in December or in March confirmed previous findings that the optimum treatment for control of blackleg (*Erwinia carotovora* ssp. *atroseptica* (Eca)) and avoiding emergence failure caused by eye death was 5 min at 55°C. However, emergence of plants of both cultivars grown from March treated seed was slower than those from seed treated earlier. When the HWT was applied to seed size tubers of eight cultivars at monthly intervals from December to April, plant growth and yield were reduced more by later than by earlier treatment, and some cultivars were affected more than others. By the end of June, growth was similar to that of the untreated controls regardless of time of treatment in the cultivars Désirée, Marfona, Kondor and Record, while in the cultivars Maris Bard and Wilja only plants from seed treated up to February and in the cultivars Estima and Maris Piper only those from seed treated in December were similar to the controls. Tuber yield at harvest was reduced only following seed treatment in March and April for all cultivars except Record which was never affected by treatment.

(E. M. Burnett, S. Melvin[1], M. C. M. Pérombelon)

The control of several seed borne fungal diseases by HWT (5 min at 55°C) was examined. The incidence of skin spot in one stock of Maris Piper treated in January and assessed in March was reduced from 92 to 2% and in another stock treated in November and assessed in January, it was reduced from 40 to 0.5%. Silver scurf and black scurf were not detected after treatment although the former was present in 16 and 29% and in the latter in 2 and 8% of the untreated tubers of two stocks, respectively. Black dot was only partially controlled in the first stock and not at all in the second.

A stock of Maris Bard severely infected with powdery scab was subjected to HWT and 4 months later suspensions of spore balls (100/ml) were made from treated and untreated tubers and applied to axenic potato bait plants. All bait plants were infected regardless of treatment but the frequency of root hair infection, gall development and powdery scab symptoms in progeny tubers was lower in those inoculated with spore balls from HWT seed compared with untreated seed. Similar results were obtained in an infected stock of Estima in which 31 and 85% of the roots of the bait plants were infected following inoculation with spore balls from HWT and untreated tubers respectively.

[1]Department of Natural Philosophy, University of Aberdeen

Tubers of Désirée were mechanically damaged, inoculated with *Phoma foveata*, exposed to HWT 10 days later and examined for gangrene symptoms after 16 wk. Severe gangrene developed on all untreated tubers but only 10% of the treated tubers were affected. When the interval between inoculation and HWT was extended to 6 wk, small lesions were present at the time of treatment and isolation tests showed that the fungus remained viable in 90% of the treated tubers.

HWT had no effect on advanced dry rot (*Fusarium coeruleum*) induced by inoculation and storage for 6 wk. Control of gangrene and dry rot by HWT may be possible if treatment was applied early whilst infection was superficial.

(E. P. Dashwood, E. M. Burnett)

Bacterial rotting of stored potatoes [PU 13(b)]

Numbers of viable cells of erwinias and clostridia (Cl) present in rotting potato tubers of various cultivars collected from different commercial stores were determined in aerobic and anaerobic conditions. Both bacteria were equally abundant in nine of the 12 samples; Cl were absent from one, and erwinias were not detected in two of the samples. *Erwinia carotovora* ssp. *atroseptica* (Eca) was the only erwinia found in rotted tissue.

Similar numbers of viable cells of Eca and Cl were inoculated either alone or in equal numbers into tubers cv. Maris Piper and incubated aerobically or anaerobically at 20°C. Under aerobic conditions only Eca and the mixed inoculum caused extensive rotting, while under anaerobic conditions only Cl and the mixed inoculum caused rotting. Enumeration of viable cells in rots under all conditions showed that Cl was equally abundant in rots in both aerobic and anaerobic environments, even when Eca was inoculated alone in air. However, Eca did not survive in anaerobic conditions when inoculated together with Cl. The results showed that both Cl and Eca were involved in storage rots and that ambient atmospheres need not be anaerobic to ensure continued activity of the former.

(N. A. Williams, D. A. Perry)

Serology of Erwinia carotovora [PU 13(a)]

Polyclonal antisera were raised against both live and heat killed (70°C, 1 h) cells of *E. carotovora* ssp. *atroseptica* (Eca) serogroup I and used in ELISA to quantify cell numbers of Eca. Although the level of detection was similar in both direct and indirect ELISA with antisera raised against dead cells, more Eca serogroups were detected using the indirect method. The level of detection of live cells was $10^6$/ml in indirect ELISA with antisera raised against dead cells and was increased to $10^5$/ml when cells were heat killed. All fime Eca serogroups were detected at this level. In indirect ELISA with antisera raised against live cells, detection level of three serogroups rose from $10^6$ to $10^5$ cells/ml following heat treatment. One

strain each of serogroup I and of XXXV were detected at $10^4$ cells/ml. Heat treatment of test bacteria failed to improve detection in direct ELISA. Several serogroups of *E. carotovora* ssp. *carotovora* (Ecc) were detected at similar cell numbers as Eca by both antisera. IgG from antiserum raised against dead cells purified by octanoic acid and ammonium sulphate precipitation gave similar detection levels and specificity for Eca as did the crude antiserum. Antiserum raised against the lipopolysaccharide of Eca serogroup I (Biochemistry Dept, University of Glasgow) gave a detection level in indirect ELISA of $10^4$ cells/ml with heat treated cells for four Eca and a selection of Ecc serogroups, with Eca serogroup I giving the strongest reaction.

Over 100 Ecc strains were screened by double immunodiffusion with antiserum raised against dead cells of Eca serogroup I to identify cross reacting strains. Adsorbing the antiserum with one strain of Ecc giving a reaction of partial identity and four giving weak precipitation lines failed to improve specificity for Eca and decreased the level of detection of both Eca and Ecc in indirect ELISA. When 57 Eca strains from Scotland were tested, 93.0% were found to belong to serogroup I or XXII, which are now believed to be indistinguishable.

(L. J. Hyman, M. C. M. Pérombelon)

Effect of tuber tissue extracts on pectate lyase activity [PU 13(b)]

Lenticels of most potato tubers are latently infected by up to $10^4$-$10^6$ cells of erwinias and to discover the mechanism of latency, extracts of tubers of the soft rot resistant cv. Record, were tested for their effect on pectate lyase from *Erwinia carotovora* ssp. *atroseptica* (Eca). Powdered acetone extract (5% w/v) from peeled tuber tissue activiated the enzyme in a saturable manner (maximum activation 52.9 ± 11.6% (N = 6)) when assayed spectrophotometrically. The activation was due to a decrease in $K_{0.5}$ rather than an increase in Vmax and the effect was unaffected by boiling the extract but was abolished by dialysis against distilled water.

Crude filtered sap extracted from tuber cores activated lyase activity when 10 $\mu$l was added to the enzyme assay mixture (1.4% v/v), whereas it caused a 50% inhibition when 35 $\mu$l (5% v/v) was added. The effects again appeared to be due to a change in $K_{0.5}$ rather than in Vmax. Boiling the sap had little effect on the activation produced by 1.4% v/v but it reversed the effect at 5% v/v, resulting in an activation similar to that at 1.4% unboiled sap. Dialysis of sap against distilled water abolished its activating effect or made 1.4% v/v and 5% v/v equally inhibitory. A similar biphasic effect was observed when the sap was extracted and tested under anaerobic conditions.

(D. Hedley, M. C. M. Pérombelon)

Effect of temperature on pectic enzyme production by Erwinia carotovora [PU 24(h)]

Previous studies showed that *E. carotovora* ssp. *atroseptica* (Eca) does not cause blackleg at high temperatures in the field and the effects of temperature on the production of pectic enzymes was investigated. The production of pectate lyase (PL) by Eca *in vitro* was approximately four times greater at 27°C than at 30.5°C and transport of lyase from within the cells to the extracellular medium was also greater at 27°C although total protein production and cell growth were similar. The lower enzyme activity observed at 30.5°C was shown by polyclonal antisera to be due to a smaller quantity of PL protein rather than an inactivation of the enzyme. Furthermore, there was no increase in protease at 30.5°C indicating that PL was not degraded. When cells were grown at 30.5°C and then inoculated into fresh medium at 27°C an increase in PL activity was observed which was sensitive to chloramphenicol, an antibiotic which inhibits *de novo* protein synthesis. All the results suggest that temperature controls the expression of genes encoding PL.

Cells grown in buffered pectate medium in these experiments produced low levels of polygalacturonase (PG). However, no significant differences in PG activity at different temperatures was recorded.

(P. Lanham, M. C. M. Pérombelon)

Analysis of novel Erwinia phages [PU 24(h)]

A number of virulent and temperate phages for *E. carotovora* ssp. *carotovora* (Ecc) SCRI 193, *E. carotovora* ssp. *atroseptica* (Eca) SCRI 1043 and *E. chrysanthemi* NCPPB 1066 have been isolated from sewage. They were characterised by u.v. inactivation, heat inactivation, host range, plaque morphology, structural morphology and DNA restriction profiles. Forty mutants of SCRI 1043 resistant to virulent phage øART-5 were isolated and tested *in planta*. One mutant, SCRI 1043/A5/22, which was avirulent was not defective in growth but lack of phage absorption suggested a cell wall alteration. All phages obtained have been assayed for generalised transduction which was found to occur in SCRI 193 using phage øKP. The generalised transduction system of that phage has been partially characterised. A number of markers have been shown to be transduced around the chromosome and their transduction frequencies determined. Conditions for optimum transduction frequencies to approximately 0.1% of the original population have been determined and include exposure of the transducing lysate to u.v. light. øKP shows a low frequency of lysogeny and is not strain specific.

(I. Toth[1], G. P. Salmond[1], L. J. Hyman, M. C. M. Pérombelon)

[1]Department of Biological Sciences, University of Warwick

*Preformed enzyme inhibitors*

The phenolic compounds benzoic acid, caffeic acid, chlorogenic acid, ferulic acid, *p*-coumaric acid, protocatechuic acid, salicylic acid, sinapic acid, syringic acid, vanillic acid and vanillin were tested for their ability to inhibit polygalacturonic acid lyase (PL) and polygalacturonase (PG) in culture filtrates of *Erwinia carotovora* ssp. *carotovora* (Ecc). None of the compounds inhibited PL at 200 $\mu$g/ml, although syringic and sinapic acids caused a 54 and 43% reduction respectively at 400 $\mu$g/ml. Caffeic acid inhibited PG by 57% at 100 $\mu$g/ml and chlorogenic acid caused slight inhibition. Little or no inhibition of PG was caused by any of the other acids. The percentage inhibition of PG by chlorogenic acid was not affected by pH over the range 4-7.

(G. D. Lyon)

*Protease inhibitors*

The production of extracellular protease by Ecc isolate 177 was strongly affected by growth conditions, e.g. little was produced when liquid cultures were grown at slow shaking speeds (70 strokes/min). It was also affected by temperature with three times the amount of enzyme produced at 27°C compared with 30.5°C. Protease activity was inhibited by 99.95 and 52% by 1mM EDTA and 10 mM cysteine respectively, 27% by 10mM thimerosal, but not by 5 mM iodoacetic acid, 100 $\mu$g/ml soybean trypsin inhibitor and 50 $\mu$g/ml pepstatin A. The results show that Ecc protease is a metalloprotease.

(J. Heilbronn, G. D. Lyon)

*Host pathogen recognition between potato and* Erwinia *spp.*

The patterns of substrate degradation of potato cell walls, sodium polypectate and citrus pectin by purified PL from Ecc and *Bacillus polymyxa* were compared. Reaction products released by both enzymes were separated by anion exchange chromatography using a 7.5 × 75 mm TSK DEAE-5PW column eluted with a linear gradient of acetate buffer pH 5.2 (50mM to 0.5 M) over 40 min, and detected by absorbance at 245 nm. The relative amounts of oligomers, especially those of unsaturated tetramers, released by both enzymes varied. Degradation patterns also varied according to the substrate used and results with citrus pectin suggested that methylation reduced the ability of Ecc PL to release wall fragments.

Oligomers released from potato cell walls by Ecc PL were pooled separately and assayed for phytoalexin elicitor activity using the soybean cotyledon bioassay. Fractions containing deca- and undecagalacturonides had the highest elicitor activity when tested at 5 $\mu$g of uronic acid per

cotyledon. These results are further confirmation that phytoalexin elicitation by cell wall oligosaccharides occurs in a wide range of plant species. This is the first evidence of the purification of oligosaccharide elicitors from *Solanum tuberosum*.

(R. S. Forrest[1], G. D. Lyon)

Epidemiology of late blight caused by Phytophthora infestans [PU 13(e)]

Growth of hyphae of *P. infestans* through potato leaves in air at different humidities in precisely controlled environment chambers was determined using ELISA. Growth was not affected by ambient humidities between 80 and 100% r.h. but sporangia were produced only in saturated or nearly saturated air.

A Burkard spore trap sampling air at 10 l/min. continuously in a field plot of potatoes cv. Bintje was used to trap sporangia of *P. infestans*. No sporangia were trapped until 3 August and blight symptoms were first visible 2 days later. Assuming that visible symptoms develop at least 7 days after inoculation, these observations suggest that sporangia had initiated the disease several days before any were trapped. Consequently, a more efficient way of detecting them is required if inoculum level is to be included in a disease prediction system. Numbers of sporangia trapped each day increased irregularly with more than 100 and 1,000 per day first recorded on 10 and 17 August respectively, and by 19 August c. 50% of the foliage was diseased.

(J. G. Harrison, R. Lowe, J. Heilbronn)

Development of immunological methods for detecting fungal pathogens [PU 13(m)]

Powdery scab, caused by *Spongospora subterranea*, can be detected by visual inspection but symptomless tubers may be contaminated by spore balls and introduce the disease into a crop. A polyclonal antiserum raised to spore balls on potato tubers contained antibodies to potato as well as to the pathogen. Antibodies to the host were successfully removed by incubating with healthy tuber tissue. The resultant antiserum detected *S. subterranea* in an extract prepared from two spore balls per ml buffer solution in a plate-trapped antigen ELISA. Contaminating spore balls on symptomless tubers were also detected. The antiserum did not cross-react with any of 10 other fungi pathogenic to potato, nor with *Erwinia carotovora*.

(E. A. Rees, J. G. Harrison)

The sensitivity of ELISA determinations of *Phytophthora infestans* in potato leaf or tuber tissues and *S. subterranea* in tuber tissue was inhibited unless the plant extract (sap) was diluted by at least 1:10,000 in plate-trapped

[1]Short-term Appointment

antigen assays. Such high dilutions are impractical if only small quantities of the antigen are present in the plant tissues. Neither the use of an inverse competitive assay system nor reducing the size of antigenic molecules by incubating test samples with catabolic enzymes reduced the inhibitory effect of sap. The inhibitory components were partially thermo-labile and were not removed by dialysis or by incubating with insoluble polyvinylpyrrolidone, indicating that they were large, non-phenolic molecules. Gel filtration confirmed that their mol. wt. was 30 to 100 kdaltons.

(J. G. Harrison, E. A. Rees)

Nature of quantitative resistance of potatoes to Phytophthora infestans [PU 24(i)]

The development of *P. infestans* in potato leaves of cultivars without major resistance genes was quantified using ELISA. The pathogen colonised leaves of Bintje faster than those of Teena and growth was slowest in Shelagh, demonstrating an effect of horizontal resistance on hyphal growth.

(J. G. Harrison, R. Lowe, J. Heilbronn)

Survival of Phytophthora infestans in soil [PU 13(d)]

Monfilament nylon packets containing oospores produced by mating A1 and A2 isolates *in vitro* were buried in July 1987 10 cm deep in a field or kept on the soil surface (*Ann. Rep. 1987,* 106). The viability of the oospores on the surface fell rapidly during late summer and autumn, but c. 80% of the buried oospores remained viable. Over the winter period the numbers of viable oospores in the buried samples declined rapidly and there was a concomitant increase in the numbers of empty oogonia, suggesting that the reduction was due largely to oospores germinating. Few viable oospores were recovered from the buried packets at the end of the winter, but the germination rates were higher than in earlier samples supporting the view that the reduction of viable oospores in buried soil was due to germination.

(J. M. Duncan, A. M. Campbell)

Fusion of protoplasts of Phytophthora infestans [PU 24(h)]

Protoplasts of *P. infestans,* produced by exposure of sporangia to NovoZym 234 in an osmoticum (*Ann. Rep. 1987,* 107), were stained with either fluorescein isothiocyanate (FITC) or tetramethylrhodamine B isothiocyanate (TRITC). By appropriate manipulation of barrier and excitation filters on a u.v. microscope it was possible to distinguish protoplasts stained green with FITC from those stained orange with TRITC. Protoplasts of isolates which differed in mating type or race were differentially stained and fused using a Zimmerman fusion apparatus. Fusion was confirmed by observing that different segments of individual

protoplasts were stained green and orange. Large protoplasts were picked out of treated suspensions with a capillary pipette, transferred singly to drops of pea broth in sorbital and examined under the u.v. microscope. Fused protoplasts, selected by their stain patterns, were kept in the droplet for several days to regenerate and form hyphae and then transferred to agar culture. Colonies from fused protoplasts of isolates which differed for mating type, race and isozyme patterns have been established and single zoospores are being analysed to determine if heterokaryons have been formed by electrofusion.

(J. M. Duncan, A. M. Campbell)

Antagonistic activity of some root and tuber fungi against potato pathogens [PU 23(f)]

Eighteen root and tuber fungi which showed antagonistic potential against *Rhizoctonia solani, Polyscytalum pustulans, Helminthosporium solani* and *Colletotrichum coccodes* in plate culture were tested for their activity on fresh potato tissue treated with an antioxidant. All of the antagonists grew well on potato; *Trichoderma viride* and *T. harzianum,* were antagonistic to all the pathogens, *Gliocladium roseum* was also inhibitory but slower to show an effect, while *Chaetomium crisptatum, Penicillium hirsutum* and *P. brevicompactum* only restricted growth of *R. solani.*

Sixteen isolates were paired with *P. pustulans* or *H. solani* on surface sterilised potato periderm discs and incubated at 15°C for up to 5 weeks. Some indigenous fungi survived surface sterilisation treatment and interfered with the interactions between the introduced fungi. *T. viride* and *T. harzianum* spread rapidly over the periderm either completely suppressing or severely restricting growth of the two pathogens. However, neither fungus controlled the spread of indigenous *C. coccodes, Fusarium culmorum,* or *Cylindrocarpon destructans. G. roseum* did not markedly inhibit the pathogens even when intermixed with them and was sometimes restricted by *C. destructans. P. brevicompactum* restricted growth of *P. pustulans,* but not of *H. solani,* nor of any other species. *C. destructans* and *Gliomastix murorum* suppressed most surface flora and partially inhibited the pathogens; *C. destructans* was more effective against *H. solani,* and *G. murorum* more effective against *P. pustulans,* while *C. coccodes* was not affected by either.

(E. P. Dashwood, D. A. Perry)

## CEREAL DISEASES

Components of partial resistance to mildew [PU 2(e)]

A restriction of the size of fungal colonies is one of several components contributing to partial resistance of barley to mildew. An estimate of colony size was obtained for advanced SCRI breeding lines by counting the

number of colonies following inoculation of leaves under controlled conditions. The numbers were related to the total fungal biomass measured by gas chromatographic analysis of fungal cell wall sterol in the inoculated leaves. Several lines expressed the restricted colony size character but preliminary results of genetical analyses indicated that this character had a low heritability. The restricted colony size character was present in lines from parents which did not express it, indicating that it may be segregating transgressively. A polyclonal antibody has been produced to obtain fungal biomass data rapidly for processing larger sample sizes.

Several mildew isolates were grown on one susceptible and two partially resistant hosts for 20 cycles of subculturing. After 10 cycles no change in their adaptation was observed, but after 20 cycles some adaptation to their recurrent host was observed.

(A. C. Newton)

Detection of interacting components of partial resistance to mildew in cultivar mixtures [PU 8(b)]

The epidemic spread of mildew is contained more effectively when barley cultivars with major genes for mildew resistance are grown in mixtures rather than alone, due to specific interactions between mildew virulence genes. Because partial resistance is polygenically controlled, there should be no interaction with mildew virulence genes and no advantage attributable to mixtures of resistant cultivars. In four trials, three-way mixtures of cultivars with partial resistance frequently exceeded the mean yields of their components when grown alone but the advantage was not related to mildew incidence or its control as both fungicide-treated and untreated plots showed similar results.

(A. C. Newton)

A novel crop protection strategy using phytoalexin elicitors [PU 8(b)]

The use of carbohydrates derived from fungi to control diseases is being investigated as a novel crop protection system. Extracts derived from yeast controlled powdery mildew on barley by eliciting resistance mechanisms within the host rather than through any direct action on the pathogen. The technique is not likely to select tolerant strains of the pathogen because no directly toxic chemicals are involved. Other putative phytoalexin elicitors are being used to manipulate expression of resistance genes in barley in order to understand the mechanisms involved.

(A. C. Newton, G. D. Lyon)

Snow rot of winter barley [PU 8(a)]

Field observations of cultivar trials which have been covered with snow have shown that cultivars differ in their susceptibility to snow rot. Although the differences recorded in the field can be reproduced in

controlled environment conditions (*Ann. Rep. 1987*, 117), spatial limitations prevent large numbers of genotypes being tested. The development of symptoms in the field depends on the presence of adequate snow cover which cannot be guaranteed and natural inoculum may be absent. To overcome these problems, artificial inoculum was prepared by culturing isolates of *Typhula incarnata* on autoclaved moist flaked barley amended with 10 g/kg sucrose at 15°C until abundant mature sclerotia formed. The inoculum was dried, ground and distributed on the soil surface around rows of established barley plants in December and the plots covered with clear polyethylene sheeting soon afterwards for a period of 12 weeks. Typical symptoms of snow rot with sclerotia developed on the leaves and the pathogen was isolated from diseased plants. Plant vigour was recorded on a 0-5 basis before inoculation and soon after removal of the sheet. Significant differences between genotypes were obtained in two successive years and the method can be used reliably to test for snow rot susceptibility regardless of the incidence of snow cover.

(N. A. Williams, D. A. Perry)

## BRASSICA DISEASES

### Clubroot resistance in kale [PU 4(k)]

A population of kale selected for resistance to clubroot (*Ann. Rep. 1987*, 63) was assessed in a field trial using transplants inoculated with three isolates of *Plasmodiophora brassicae*. Only 32.5% plants of the improved populations were galled in October compared to 59.0% in the base population and 69.1% in cv. Kestrel. Galls on plants were smaller and DM yields were higher from the improved than from the base population, or from Kestrel ($p<0.001$).

Twelve kale cultivars including the improved population, two cabbage cultivars and nine experimental *Brassica oleracea* accessions were inoculated with six isolates of *P. brassicae* in a glasshouse test. The mean disease index in the improved population was 12.5% compared to 41.1% in the base population and 59.0% in Kestrel. Only the cabbage Bohmerwaldkohl showed resistance equivalent to that of the improved kale. The ranking of the 23 hosts was similar for each of the six inocula and there was no evidence of differential resistance.

(C. J. Williamson, J. E. Bradshaw)

### Influence of environment on host-pathogen interaction in Plasmodiophora brassicae [PU 10(a)]

Although most winter oilseed rape cultivars have no differential genes for resistance to *P. brassicae*, symptoms of clubroot are rarely seen in the crop. Experiments in controlled environments have confirmed earlier results

that symptoms did not develop below mean daily temperatures of 7°C. With a daily temperature cycle of 2 and 12°C, severe galling only occurred when at least 12 h illumination was given at the higher temperature. When either the period at 12°C or the length of illumination were reduced, the mean percentage galled plants from four oilseed rape cultivars was reduced from 90.6 to 4.4 and 13.3% respectively.

(C. J. Williamson)

Components of partial resistance to powdery mildew in swede [PU 24(j)]

Resistance to powdery mildew was examined in seedlings from 11 inbred swede lines with a range of susceptibilities to *Erysiphe cruciferarum*, and in 55 progenies from crosses generated by the Brassica Genetics Department (see page 64) by inoculating young plants with a local population of the pathogen. Two parental lines which had a high level of adult plant resistance in the field showed seedling resistance in the glasshouse test while a third line was only resistant in the adult stage. When early stages of colony development were examined on leaf discs taken from the second true leaf 7 days after inoculation, 80% conidia had germinated and produced sporulating colonies in the susceptible seedling line, while 34 and 23% of conidia had germinated, and only 2 and 15% of young colonies were sporulating in the two resistant lines.

(C. J. Williamson)

## SOFT FRUIT DISEASES

Phytophthora root rot of raspberry [PU 9(a)]

*Field trial*

A number of candidate fungicides for root rot control identified in pot tests (*Ann. Rep. 1987*, 111) were included in a field trial. Only metalaxyl plus copper at two rates and oxadixyl plus mancozeb gave satisfactory control. The higher rate of metalaxyl plus copper (20 kg/ha Ridomil plus) gave better control than the currently recommended lower rate (8.3 kg/ha) as shown by height and numbers of healthy new canes and the vigour of fruiting canes. When isolations were made from plant material collected from the trial at 2-monthly intervals throughout the year, the pathogenic *P. megasperma* was isolated on 11 occasions, but recovery was best in June when there was less contamination from other fungi. The same fungus was isolated from control plots and plots treated with metalaxyl plus copper, indicating that the fungus was not eradicated from fungicide treated plants despite their improved growth.

(P. H. Scott[1], D. M. Kennedy, J. M. Duncan)

[1]Short-term Appointment

*Examination technique for planting stocks*

Roots from samples of stocks under test were layered in trays of UC compost and held under conditions suitable for root and shoot production (22°C, with supplementary lighting). After shoot formation, the trays were transferred to conditions suitable for disease development (15°C, abundant water) and 5 wk later samples infected with *P. megasperma* could be identified easily by aerial symptoms, and those infected with *P. cactorum* were determined by microscopic examination for oospores in the new root growth.

(J. M. Duncan, D. M. Kennedy)

*Taxonomic affinities of* Phytophthora *spp. isolated from raspberry*

The whole protein patterns from mycelial extracts of some species of *Phytophthora* isolated from raspberries affected by root rot have been examined using SDS polyacrylamide gel electrophoresis (PAGE). Intra-specific variation in the resultant patterns was less than that observed between species, and the technique can be used to identify isolates recovered from affected plants. Protein patterns confirmed that previously unidentified isolates of a type commonly found in high-grade planting stocks were an atypical form of *P. cactorum*. There was little variation in the patterns from isolates of the pathogenic *P. megasperma* from the British Isles, continental Europe and N. America confirming that all of them belonged to a single, perhaps new species specific to raspberry. It could readily be distinguished from closely related species such as *P. fragariae*.

(P. H. Scott[1], J. M. Duncan, D. M. Kennedy)

Rubus *hybrids and root rot*

Five *Rubus* hybrids and the thornless blackberry cv. Loch Ness were inoculated with the pathogenic *P. megasperma* but no disease was observed when plants were subjected to 7 days waterlogging after inoculation. However when Tayberry was inoculated in another experiment, severe root rot with aerial symptoms was observed after a period of 12-16 days prolonged waterlogging.

(D. M. Kennedy, J. M. Duncan)

*Resistance to* Phytophthora megasperma

The progeny of 16 crosses of several *Rubus* hybrids from the breeding programmes at SCRI and IHR (East Malling) were tested for resistance to root rot following inoculation with pathogenic *P. megasperma*. Three crosses yielded a high percentage of resistant progeny. A common parent was a second backcross derivative of *R. coreanus* and the other parents were cv. Latham, a second backcross of *R. spectabilis*, and a second backcross of *R. piliatus*.

[1]Short-term Appointment

In pot tests, the two most promising selections were a second backcross hybrid of *R. piliatus* to raspberry, and an advanced generation hybrid derived from a *R. crataegifolius* clone from Russia. Three autumn fruiting red raspberry cultivars were moderately or highly susceptible to *P. megasperma*.

The effect of varying inoculum level on disease assessment was tested by inoculating four red raspberry cultivars with 100 ml inoculum per plant containing 10, 30, 100, 300 and 1000 zoospores/ml. There was no difference in the severity of disease between the lowest and highest inoculum levels in the most susceptible and resistant cultivars but one cultivar with intermediate resistance was less stunted and had fewer wilted leaves at lower zoospore concentrations.

(D. M. Kennedy, D. L. Jennings[1], V. Knight[2], P. H. Scott[3], J. M. Duncan)

Pathogenicity of Phytophthora fragariae [PU 24(h)]

The number of zoospores of *P. fragariae* required to initiate disease in a susceptible alpine strawberry seedling, estimated by Most Probable Number analysis, varied from 10 to 30 zoospores per plant and was used to determine the amount of secondary inoculum produced by infected plants. Drainage water was collected at intervals from plants held at 8, 14, 20 and 26°C and baited with susceptible seedlings. The optimum temperature was 14°C at which c. 4000 zoospores per plant were produced 4 weeks after inoculation. Similar numbers were produced at 8°C but at a later stage. Few zoospores were obtained at 20°C and none at 26°C. Maximum production of oospores within the roots of the inoculated plants 2 weeks after inoculation occurred at 14°C.

(D. M. Kennedy, J. M. Duncan)

Downy mildew of Rubus cane fruits [PU 9(a)]

Outbreaks of downy mildew caused by *Peronospora rubi* have occurred in England during the last 3 years on blackberry and blackberry × red raspberry hybrids during propagation, particularly on newly weaned, micropropagated plants. Similar outbreaks have been reported recently from Washington, California and in New Zealand. The source of inoculum for recent outbreaks is obscure. Microscopic examination of *in vitro* stocks of a range of blackberry, red raspberry and hybrid berry cultivars from England revealed no evidence of systemic mycelium of the fungus and diseased wild blackberry is the most likely origin of the inoculum in UK (*Ann. Rep. 1985*, 91).

Detached leaves of blackberry cv. Loch Ness, the red raspberries SCRI 42E6 and cv. Autumn Bliss, and the hybrid cultivars Tummelberry,

[1]Soft Fruit Genetics Department
[2]IHR (East Malling)
[3]Short-term Appointment

Tayberry and Sunberry from plants grown *in vitro,* were inoculated on the abaxial surface with 10,000 conidia/ml of *P. rubi.* The leaves were incubated at high humidity under diffuse lighting (25 $\mu$ mol/($m^2$.s)) at c. 15°C, sampled at 3, 5, 11 and 21 days, stained in aniline blue and examined by fluorescence microscopy. Germ tubes of *P. rubi* penetrated epidermal cells or sometimes entered stomata of all the genotypes. Hyphal growth in the mesophyll of Sunberry was restricted and no sporulation occurred, but in the other genotypes hyphae grew intercellularly throughout the mesophyll (Fig. 1), entered the veins and spread into the petiole. Conidia were produced on both the abaxial and adaxial leaf surface before symptoms appeared and oospores were produced prolifically within all infected tissues within 11-21 days (Fig. 2). In this experiment, micropropagated raspberries were as susceptible to downy mildew as hybrid berries and blackberries, but the results may not relate to the susceptibility of the genotypes in the field. However, the ability of the disease to spread to red raspberries during the propagation phase in UK is an important finding.

(B. Williamson, W. A. Wallis[1], R. C. Shattock[1])

Control of post-harvest grey mould (Botrytis cinerea) with natural fruit volatiles [PU 9(a)]

Testing continued of volatile compounds from fruits as antimicrobial agents to control post-harvest grey mould in soft fruits (*Ann. Rep. 1987,* 113). Fruits of red raspberry cv. Delight were wound inoculated with conidia of *B. cinerea* and incubated at 20°C in an atmosphere of high humidity and one of a series of volatile lactones, each at 785 $\mu$l/l. Most fruits survived >5 days in an atmosphere of $\gamma$-caprolactone, but grey mould developed more rapidly with $\gamma$-valerolactone, $\gamma$-octalactone and $\delta$-decalactone in descending order of activity. In an atmosphere of 100 $\mu$l/l $\gamma$-caprolactone 50% of fruits of cv. Glen Prosen survived for 6 days. Wounded and inoculated fruits incubated at high humidity in the absence of lactones rotted and were discarded after 2 days.

(B. Williamson)

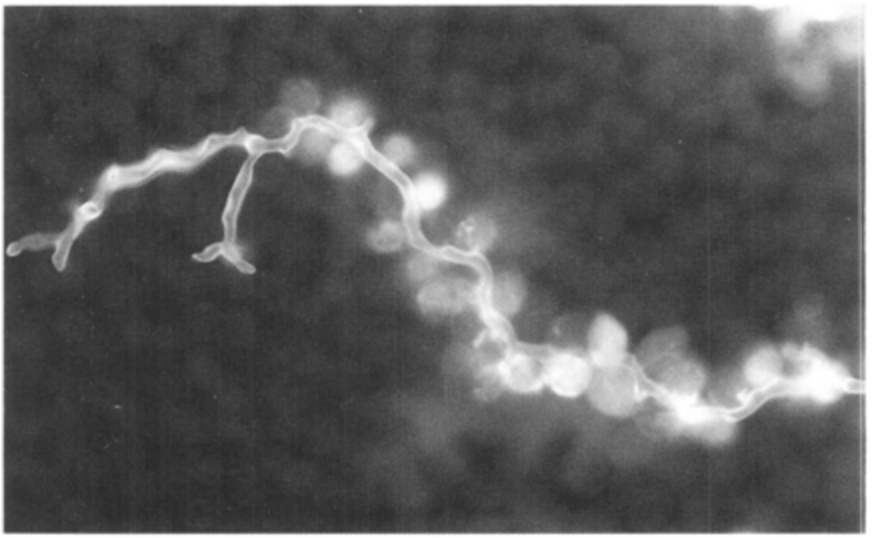
## SOIL MICROBIOLOGY

Soil respiration studies [PU 23(b)]

Recent modifications to the substrate-induced respiration (SIR) assay for microbial biomass C, involving the removal of water limitation, were investigated in relation to some arable soils. Static incubation at high volumes of solution amendment were found to severely inhibit SIR due to oxygen limitation. Agitation removed this limitation, resulting in increased SIR and discrimination between six soils.

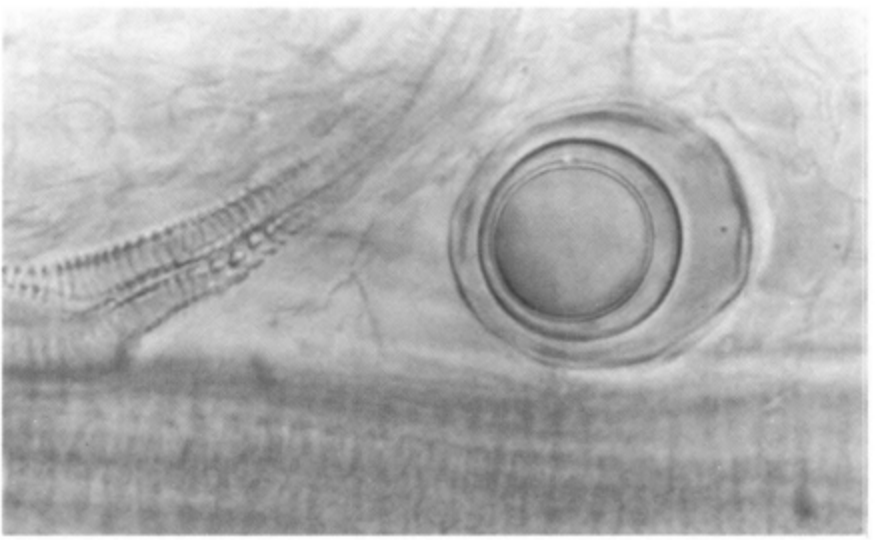
[1]School of Biological Sciences, University College of North Wales

Figure 1



**Intercellular mycelium of *Peronospora rubi* in mesophyll of Tummelberry leaf. Cells penetrated by haustoria fluoresce strongly (X320).**

Figure 2



**Oospore of *Peronospora rubi* in leaf of Tummelberry (X1266).**

Freezing was an effective means of preserving samples for soil respiration studies.

(K. Ritz, R. E. Wheatley)

Direct extraction of microbial biomass carbon [PU 23(b)]

Soil microbial biomass C can be estimated by measuring C released following lysis of microbial cells with chloroform. The C can be measured either as $CO_2$ evolved during a 10 day incubation or more rapidly by extraction into a salt solution. Nine solutions were tested for their efficacy in extracting dissolved organic carbon (DOC) from a wide range of soil types before and after treatment with chloroform. Generally, more C was evolved as gas than was extracted into solution. Amounts of DOC extracted correlated very highly with amounts of $CO_2$ evolved during incubation for all extractants tested. Thus using the direct-extraction procedure biomass measurements can be made more rapidly than by the 10 day incubation method.

(K. Ritz)

Nitrogen transformations under different plant species [PU 23(b)]

Several soil microbiological parameters (*Ann. Rep. 1987*, 119) were measured in unfertilised soil in pots planted with barley, grass, turnips and peas, or unplanted. After 10 weeks the dry weight and N content of the barley, turnips and grass were similar but the peas were 2.5 times heavier and contained 10 times more N. During this time microbial biomass N, but not C, progressively increased. There was no detectable effect of the plants upon biomass C or N, respiration rate, nematode or protozoan biomass. There was an inconsistent effect of plants on dehydrogenase activity and potential nitrification and denitrification rates varied with the developmental stage of the plants.

(K. Ritz, R. E. Wheatley, B. S. Griffiths)

Nitrate in soils [PU 23(b)]

An improved method for measuring nitrification in soils was developed using moistened soils agitated on a roller bed. Plants growing in soil depressed the nitrification rate during the growing period and incubating soils with added carbon, or with a slightly increased $CO_2$ concentration in the atmosphere increased the rate of nitrification. Nitrous oxide was released from soil during nitrification, frequently in greater amounts than from the same soil during optimum denitrification, and rates of denitrification were also affected by the type and stage of development of growing plants.

(R. E. Wheatley)

# ZOOLOGY

D. L. TRUDGILL

In agricultural research, 'basic', 'strategic' and 'applied' (near market) research are terms often used for studies that are in practice a continuum. Studies involving these three aspects of research form part of the Zoology Department's programme. However, there is a growing need for more basic research, especially to provide alternatives to what many regard as the present-over-reliance on pesticides. To achieve this shift in the balance of the research programme, an appointment was made in 1988 to provide a more molecular approach to the research on the mechanisms and genetic base of host plant resistance and susceptibility and pest virulence.

Nematodes and protozoa in the rhizospheres of different plants [PU 23 (b)]

Growing roots release complex exudates which provide food for large numbers of bacteria which develop in the rhizosphere. These bacteria are consumed by protozoa and certain nematodes which subsequently excrete nitrogen into the soil, thereby increasing nutrient cycling. The relative importance of these two groups of animals in this process was determined in two different soils which received high or low rates of inorganic fertiliser by measuring the biomasses of both nematodes and protozoa in bulk and in rhizosphere soil of pot-grown barley, pea, turnip and grass.

Nematodes were the most abundant consumers of microorganisms in the rhizosphere soil (Table 1). Although the total number of nematodes in the pots only increased after 7 weeks, the rapid increase in rhizosphere populations from 24 to 173 nematodes/g of pea rhizosphere soil after 1 week suggests that migration from the surrounding bulk soil is important. Also, nematodes release more nitrogen per unit of food than do protozoa which suggests that they are more important for the rapid turn-over and release of plant-available nitrogen in the rhizosphere.

(B. Griffiths)

**Table 1. The biomass, ug dry weight per g dry soil, of microbial feeding nematodes and protozoa in the rhizosphere after 7 weeks growth**

| | *Pea* | *Barley* | *Grass* | *Turnip* |
|---|---|---|---|---|
| Nematode | 9.01 | 5.60 | 4.68 | 1.90 |
| Protozoa | 0.18 | 0.15 | 0.25 | 0.15 |

The transmission of serological variants of tobraviruses by (Para)Trichodorus species [PU24 (e)]

As previously reported, distinct strains of nepoviruses have specific Longidorid vectors but, until recently, techniques were lacking for studying the specificity of the association between the many different strains of tobraviruses and their Trichodorid vectors. Using recently developed methods virus transmitted by single, naturally infected Trichodorid nematodes from England, Scotland, the Netherlands* and Sweden* was collected and characterised using a range of strain-specific antisera. The species of individual nematodes transmitting each virus was then determined. The results (Table 2) show that *P. teres* from the Netherlands transmit an isolate of virus which is serologically indistinguishable from a strain from Oregon, USA. This is the first record of serologically identical isolate of a tobravirus occurring in North America and Europe. Isolates of virus transmitted by *P. pachydermus* from sites in three different countries each reacted to an antiserum prepared against strain PRN.

Serologically distinct strains of tobacco rattle virus were each transmitted by different Trichodorid species from Barry, Scotland.

These results provide preliminary evidence that (*Para*)*Trichodorus* species transmit specific serological variants of tobraviruses.

(D. J. F. Brown, A. T. Ploeg[1], D. J. Robinson[2])

**Table 2. Specific associations between (*Para*)*Trichodorus* species and serological variants of tobraviruses**

| *Site location* | *Nematode species* | *Nematodes transmitting virus* | *Tobravirus strain* |
|---|---|---|---|
| Scotland: | | | |
| Barry | *Paratrichodorus pachydermus* | 11/152 | PRN |
| Barry | *Trichodorus cylindricus* | 11/192 | B28 |
| Kinshaldy | *P. pachydermus* | 21/200 | PRN |
| Morton | *P. pachydermus* | 3/20 | PRN |
| Scryne | *T. cylindricus* | 1/42 | TC |
| England: | | | |
| Oxford | *T. primitivus* | 4/25 | RQ |
| Lincolnshire | *P. anemones* | 13/60 | PA |
| Netherlands: | | | |
| Wageningen – Hoog | *P. pachydermus* | 7/31 | PRN |
| Wageningen – Hoog | *P. teres* | 30/42 | Oregon |
| Sweden: | | | |
| Alnarp | *P. pachydermus* | 1/35 | PRN |

[1]Research Student
[2]Virology Division
*Held under DAFS licence

Transmission of isolates of arabis mosaic (AMV) and raspberry ringspot nepoviruses (RRV) by Xiphinema diversicaudatum, Longidorus elongatus and L. macrosoma [PU 24(f)]

Considerable serological variation occurs amongst RRV isolates, whereas AMV isolates are indistinguishable serologically but differ in their host range and symptomatology (*Ann. Rep. 1987,* 186). To test whether AMV isolates also differ in transmissibility a Scottish population of *X. diversicaudatum* was exposed to nine isolates from Britain, three from Germany (FGR) and one from Czechosolvakia. All isolates were transmitted equally well with c. 80% of nematodes acting as vectors.

In similar experiments with a population of *L. elongatus* from Scotland three out of four isolates of RRV from Scotland were transmitted by an estimated 0.06, 0.03 and 0.01 of the nematodes whereas virus isolates from England, Germany FGR*, Greece*, Switzerland* and Turkey* were not transmitted. Also, in experiments with *L. macrosoma* from England two isolates of RRV from Scotland and one each from Germany FGR*, Greece*, Turkey* and Switzerland* were not transmitted. An isolate from England was transmitted but only <0.05 of the *L. macrosoma* were estimated to have acted as vectors. However, with the exception of the virus isolates from Greece and Turkey which did not react with antiserum prepared to the type Scottish-strain of RRV, virus particles were detected by immunosorbent electron microscopy in suspensions of *L. macrosoma* allowed access to plants infected with all the other virus isolates.

(D. J. F. Brown, A. T. Jones[1], M. M. Mitchell[1], D. L. Trudgill)

Plant host recognition by nematodes [PU 15(a)]

Several stimuli appear to be involved in the location by nematodes of their invasion sites on plant roots and specific feeding sites. In a bioassay test using impregnated agar discs it has been shown that there is a rapidly diffusable component from potato roots which attracts the invasive juveniles of potato cyst nematodes from a distance of 5 mm within the first 1 h of exposure. The proportion of juveniles attracted showed a further increase between 2 and 4 h, suggesting that the nematodes are responding to a second, slower diffusing component. Also, some nematodes tend to aggregate against the floor of the plastic petri dish, indicating an additional tactile response. After 18 h the proportion attracted was the same as that after 4 h.

The response to the chemicals diffusing from plant roots is thought to be mediated by the amphids, a pair of sense organs on the head of nematodes. The amphids produce a plug of glycoprotein exudate, the outside of which labels strongly with the lectin conA. To test whether blocking the function

[1]Virology Division
*Held under DAFS licence

of the amphids would interfere with the ability of the nematodes to locate and invade roots, 200 ppm conA was added in buffer at pH 6.5 to tomato seedlings growing in sand infested with juvenile rootknot nematodes (*Meloidogyne* spp); the invasion and gall formation was reduced by c. 70%. However, the effect was partly pH dependent, possible because the conA tends to change from the dimer to the tetramer as the pH increases.

(W. M. Robertson, L. MacCulloch[1], J. M. S. Forrest, N. A. R. Gow[2], Y. Spiegel[3])

Studies on resistance breaking populations of Meloidogyne incognita

Nematodes of the genus *Meloidogyne* are major pests in tropical areas. Resistant cultivars would provide the most efficient and simplest method for their control in Third World countries but populations able to overcome the resistance of different cultivars have been found.

Work was started to study the relationships between virulent and avirulent populations of *M. incognita*, and to develop an easy method of identifying virulent populations.

The specific binding of lectins on the surface of the juveniles showed the presence of glycoproteins, mostly on the amphid apertures, but no difference between virulent and avirulent populations was detected using a range of specific lectins. The yield of components which could be stripped off the cuticle surface was too small to allow study of the glycoproteins by electrophoresis.

Nevertheless, isoelectric focusing of proteins from females showed isozymic differences in five out of nine enzyme systems studied, suggesting that virulent and avirulent populations may be distinct taxonomical entities. Furthermore, the total protein patterns (isoelectric focusing and SDS PAGE) showed some differences within the group of virulent populations.

Such virulent populations should be taken into account in plant-breeding programmes against *Meloidogyne* spp.

(M. Fargette[4])

Rates of selection of virulence of potato cyst nematode (PCN) on potatoes with quantitative resistance [PU 13(1)]

For many years cultivars of potatoes with the major $H_1$ gene for resistance to PCN have been grown at sites in Britain infested with *Globodera rostochiensis* with no indications that this nematode is being selected for increased virulence. However, the incidence of *G. pallida*, against which the $H_1$ gene is ineffective, has increased.

[1]Research Student
[2]Department of Genetics and Microbiology, University of Aberdeen
[3]Nematology Division, Volcani Centre, Bet Dagan, Israel
[4]Visiting Worker

Resistance to *G. pallida* in potato cultivars has been derived from *Solanum vernei* and *S. andigena* CPC 2802, but this resistance is only partial (i.e. some new cysts are produced) and the repeated growing of cultivars with such resistances may select for increased virulence in *G. pallida*. To examine this possibility populations are being reared repeatedly on representative clones from the SCRI breeding programme.

The effects of selection on the numbers of cysts produced by three such populations on a susceptible cultivar have been compared with those produced on three ex *vernei* (cv. Morag, 62-33-3 and cv. Vantage) and two ex CPC 2802 (11415 and 1674) clones (Table 3). Lines from Bedale and Halton populations had been selected for 6 years either on Morag or on clone 11415, and the line CA population had been selected for 9 years on clone 62-33-3.

Some selection for increased virulence has occurred but it is variable and sometimes not very specific. The degree of selection is least with Bedale, initially the most virulent of the three populations. Compared with the unselected line, selection on Morag significantly increased the numbers of cysts (expressed as a percentage of that on the non-resistant control cultivar) only on Vantage and clone 12674. Selection on clone 11415 significantly increased virulence only on clone 62-33-3. In contrast, selection of the Halton population on Morag or clone 11415 significantly increased virulence on all except Vantage and clone 12674 (Morag line only).

With the CA population, selection on clone 62-33-3 gave a similar result to that obtained with the Halton; virulence was increased on all the test clones except 12674 and significantly so on clones 62-37-3 and 11415.

These results indicate a complex situation in which selection for virulence has occurred to varying extents depending on the PCN population and host genotype. It seems likely that a number of resistance/virulence genes are involved and that *S. vernei* and CPC2802 may share some resistance genes in common. In contrast, it is also evident that selection for increased virulence on one host genotype does not necessarily confirm increased virulence on all others.

(M. S. Phillips)

Production of antibodies to potato cyst nematodes (PCN) [PU 24(a)(g)]

Once juvenile cyst nematodes have invaded the roots of their host, they settle down to feed. Here they induce changes in adjacent cells which form an enlarged, metabolically highly active syncytium. This provides the food that enables them to develop into adults. One irreversible change which occurs in the roots of infested resistant potatoes is breakdown of the syncytial cell wall at the head of the juvenile nematode. This breakdown is thought to be elicited by nematode products and it is hypothesised that nematode surface components are involved.

**Table 3. Cysts from populations of *Globodera pallida* reared on five quantitatively resistant clones expressed as % of these on non-resistant cv. Désirée.**

| | *Bedale* | | | *Halton* | | | *CA* | |
|---|---|---|---|---|---|---|---|---|
| Source of population | Unselected | Morag† | 11415‡ | Unselected | Morag† | 11415‡ | Unselected | 62-33-3† |
| cv. Morag† | 16 | 25 | 13 | 7 | 25* | 26* | 12 | 23 |
| 62-33-3† | 13 | 20 | 27* | 5 | 18* | 26* | 10 | 70* |
| cv. Vantage† | 10 | 21* | 7 | 6 | 13 | 10 | 12 | 18 |
| 11415‡ | 36 | 26 | 41 | 13 | 21* | 67* | 27 | 44* |
| 12674‡ | 1 | 7* | 18* | 1 | 1 | 12* | 3 | 1 |
| Mean | 15 | 20* | 18 | 7 | 16* | 32* | 14 | 32* |

†Ex *vernei*

‡Ex CPC 2802

*Significantly different (P 0.05) from the unselected population

To isolate and identify the small quantities of secretory/excretory nematode products which lead to the end of syncytial development, polyclonal antibodies were raised in rabbit and mouse to whole PCN juveniles. Antibodies to the surface of juveniles of *Globodera rostochiensis* and *G. pallida* were highly cross-reactive. They were visualised both by immunofluorescence and transmission electron microscopy. These antisera also bound on nitrocellulose to nematode homogenates or to protein bands separated by electrophoresis.

Alginate beads containing many nematodes were fixed, infiltrated with resin and sectioned to examine the sites where different antibodies bound. Immunofluorescence studies showed that antibodies to whole juveniles bound to internal as well as surface antigens.

*Narcissus pseudonarcissus* agglutinin (NPA), a lectin specific only for mannose, was isolated from daffodil bulbs and it was shown that NPA-tetrarhodamine isothiocyanate would bind to the amphidial exudate of *G. rostochiensis* and *G. pallida*. However, binding was blocked by ∝-methyl mannoside, demonstrating unequivocally for the first time that mannose is present in the amphidial exudate.

(J. Robb[1], D. Stewart[1], J. M. S. Forrest)

Nematodes associated with cereals in Scotland [PU 8(c)]

A range of plant-parasitic nematode species are known to attack and damage cereals in England and Wales. Under intensive cereal cultivation populations of the cereal cyst nematode (CCN) *Heterodera avenae* are generally held at low levels by nematophagous fungi. However, after dry summers, when the fungi do not control the nematode efficiently, CCN can become a major pest.

A survey of 98 cereal fields to ascertain the geographical distribution and the population densities of this nematode in Scotland indicated that 69% of the fields were infested and 54% contained viable eggs. CCN infestations were most frequent in eastern Scotland, but populations were generally small; 71% of the samples had less than 1 egg/g soil and only 3% had more than 6 eggs/g soil. Infested fields were most frequently found in free-draining loamy soils, especially those frequently cropped with cereals. Oats had been grown often on fields with the largest nematode populations.

In a parallel assessment for potato cyst nematode, 55% of the samples also contained CCN, and potatoes grown on these infested fields would not be suitable for export to countries requiring consignments of seed potatoes free from *Heterodera* species.

An experiment to investigate the relationship between CCN densities and yield loss was started in 1987. CCN populations were manipulated by a pre-planting treatment with formalin which controls CCN less well than its

[1]Short-term Appointment

larval root damage induces a shift in glucosinolate metabolism. The total root glucosinolate content generally is decreased, whilst the proportion of aromatic to aliphatic glucosinolates is increased mainly due to a greater than 80% increase in one indole-based glucosinolate and decreases of 39-56% in aliphatic glucosinolates. These induced changes in glucosinolate metabolism may be associated with differing degrees of tolerance or resistance, and may also have important consequences for production of brassicas with low thresholds for specific antimetabolites.

(A. N. E. Birch, J. E. Bradshaw[1], W. H. Macfarlane Smith[1], D. W. Griffiths[2])

Insect contamination of raspberry fruit harvested by machine [PU 9(b)]

Only a few of the many arthropods associated with raspberries cause damage or affect yield. Although hand-picked fruit is rarely contaminated by insects, they may be dislodged and collected with fruit harvested by machine which shake the whole plant.

Trials were made from 1985 to 1987 to examine the insect contaminants of fruit harvested by machine and to assess the effectiveness of a pretreatment with the synthetic pyrethroid insecticide, deltamethrin (Decis), in controlling them. A 1980 model Littau raspberry machine harvester (*Ann. Rep. 1985*, 131) was used at a shaking frequency of 2.1 Hz in a mature plantation cv. Glen Clova and samples of fruit from each pick were examined.

Aphids (mainly *Amphorophora idaei*) were the most common contaminant, followed by the European earwig (*Forficula auricularia*), spiders (e.g. *Enoplognatha ovata, Lepthyphantes* sp.) and harvestmen (*Mitopus morio*). Low numbers of Coleoptera and Lepidoptera were also found. Of the groups present in any numbers, it is earwigs that will pose most problem to processors because of the size and hard exoskeleton of the insect. However, the range and number of arthropods sampled is much less than those in machine harvested crops in the Pacific Northwestern States of USA and Canada.

Deltamethrin applied at 1 or 7 days before harvest significantly reduced ($P = <0.05$) the total numbers of arthropods contaminating machine-picked raspberries.

(S. C. Gordon, M. R. Cormack[3])

The occurrence of insect parasitic nematodes in Scotland [PU 23(g)]

Insect-parasitic nematodes belonging to the families Heterorhabditidae and Steinernemitidae are potential control agents of a number of important insect pests e.g. vine weevil (*Otiorhynchus sulcatus*) and house

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[2]Chemistry Department
[3]Physiology and Crop Production Department

fly (*Musca domestica*). The non-feeding infective juveniles live in the soil and invade the insect host through body openings or interskeletal membranes. Symbiotic bacteria released from the nematode's intestine then multiply causing septicaemia and the death of the insect. The use of entopathogenic nematodes as biological control agents has been limited to countries with climates warmer than Scotland, although reports from Scandinavia and Northern Ireland suggest strains or species of nematodes exist which can tolerate cooler soils.

An investigation to ascertain if entopathogenic nematodes occurred in Scotland found juveniles in only seven out of 406 soil samples baited with *Galleria mellonella* (wax moth) larvae. The positive samples were collected from a range of habitats, from as far north as Ballater and as far south as Wigtown, and the species present in all seven samples was confirmed as *Neoaplectana bibionis*.

Future work will study the ecology and population dynamics of the different isolates to ascertain the factors limiting their population size and their low frequency of occurrence in the samples examined.

(R. Neilson, S. C. Gordon, B. Boag)

Epidemiology of potato leafroll virus (PLRV) [PU 13(f)]

*Macrosiphum euphorbiae* has been the most numerous species of aphid found in potato crops in Scotland in recent years but its role in the epidemiology of PLRV was unclear. Although the population density of *M. euphorbiae* has been positively correlated with PLRV spread in the field, rates of transmission by *M. euphorbiae* collected from infected potato plants were low (*Ann. Rep. 1983,* 142). Further investigations were hampered by lack of a suitable test plant, but *Nicotiana clevelandii* has been found to be a good host for both *M. euphorbiae* and *Myzus persicae* and to show clear symptoms when infected with PLRV.

Using single aphids (adult apterae) allowed a 2 day acquisition feed on infected *N. clevelandii* and a 4 day inoculation feed on 2-3 wk old *N. clevelandii*, only one out of 164 *M. euphorbiae* transmitted PLRV, compared with 23 out of 102 *M. persicae*. Transmission rates for aphids of both species collected from potato crops in Tayside and East Lothian increased when they were given a 9 day acquisition feed, with only two out of 15 clones of *M. euphorbiae* being non-vectors; for most clones the estimated proportion of aphids transmitting PLRV was low (0.04-0.23) compared with that for *M. persicae* (0.62). However, transmission rates of 0.24-0.30 were found in four clones of *M. euphorbiae*.

(J. A. T. Woodford)

Epidemiology of potato leafroll virus (PLRV) [PU 13(f)]

In many crops, aphid-transmitted viruses spread rapidly because newly infected plants rapidly become infective and are an additional source of

virus. However the spread of PLRV from current season ('primary') infections has been shown to be insignificant in Scottish conditions, but these could become important if the climate becomes warmer.

In aphid transmission studies of PLRV from plants with primary infections in a glasshouse at c. 20°C PLRV was detected by ELISA after 2-4 weeks in plants that had been inoculated when 2-4 weeks old, but not until after 4 weeks in plants that were 6-8 weeks old at inoculation. ELISA absorbance values were higher in young leaves than in older leaves close to the inoculation sites. Also, aphid transmission rates were lower than from similar aged plants with secondary infections, and older plants were less good sources of virus than those infected when young (Table 4).

(J. A. T. Woodford)

**Table 4. Primary infection with PLRV and transmission by aphids from cv. Maris Piper potato**

| Age (wk) at inoculation | Wk after inoculation | *Inoculation method* | | | | Secondary infectors | |
|---|---|---|---|---|---|---|---|
| | | Aphids | | Grafting | | | |
| | | Detection† | Transmission‡ | Detection† | Transmission‡ | Age (wk) | Transmission¶ |
| 2-4 | 1 | 0/9 | 0/17 | 0/15 | 0/15 | | |
| | 2 | 6/20 | 1/20 | 4/15 | 2/17 | 4 | 17/35 |
| | 3 | 6/18 | 2/16 | 7/17 | 1/17 | | |
| | 4 | 8/20 | 0/13 | 9/18 | 3/12 | 5 | 16/58 |
| 6-8 | 1 | 0/10 | 0/9 | 0/10 | 0/9 | 6 | 4/21 |
| | 2 | 0/10 | 0/15 | 0/10 | 0/11 | | |
| | 3 | 0/15 | 0/13 | 0/8 | 0/12 | 7 | 0/5 |
| | 8 | 4/15 | 1/15 | 8/15 | 0/10 | | |

†Number of plants infected (ELISA) out of number inoculated

‡Number of plants from which aphids transmitted PLRV to *Nicotiana clevelandii* out of number tested

¶Number of *N. clevelandii* infected out of number inoculated after *Myzus persicae* fed on secondary infectors.

# PHYSIOLOGY AND CROP PRODUCTION

H. M. LAWSON

The research programme of the Department was modified considerably over the last twelve months in response to the changing remit of the Institute, the appointment of staff with expertise in more basic disciplines, and the increasing opportunities for cooperation in the use of new expertise and facilities available in other Departments. Physiological research in crops other than potato is increasing. Outside funding has been sought to support continuation of work on applied projects considered important to the maintenance of a broad-based programme of research, and for new projects in areas in which staff have appropriate expertise.

The formation of the Roots, Soils and Simulation Group has added a major new dimension to the Department's research capabilities, complementing the work of the plant and crop physiologists. Physiological processes can now be considered in the context of the total soil/plant/atmosphere system, and include feedbacks, mechanisms and dynamic interactions with the environment. Close liaison is maintained with the soil microbiology group in the Crop Protection Division. Current research by the new group includes the characterisation of the soil physical environment in relation to root growth, activity and function, the investigation of nutrient equilibria in soil solution within the rooting zone and their effect on nutrient inflows, and studies of root and shoot balance in arable crops as affected by nutrient and carbon supply.

Experiments in environmental physiology show a diversity of response of potato cultivars to drought, with genotype × environment interactions in root growth, extension rates of leaves and osmotic adjustment. These results will be used to model ideotypes of potato for responses to particular forms of drought.

A detailed study of the enzymes involved in sucrose to starch conversion in potato has shown that sucrose synthase, one of the enzymes responsible for sucrose breakdown, is suppressed substantially following tuber detachment from the parent plant.

## POTATO

### Potato: the occurrence of 'twins'? [PU 5(d)]

In a joint study with University of Wageningen, the possible phenomenon of twinning was investigated. Twinning is the apparent preference for

tubers to grow in groups of similar size rather than as a smooth distribution of individual sizes. A pair of tubers is defined arbitrarily twins when the difference in their weights is less than 10% of their average weight. Two hundred plants were lifted individually on each of three harvest dates from a field crop and fresh and dry weights of each tuber were recorded. Tubers belonging to an individual plant were ranked by weight and the number of apparent twins was determined. A log-normal distribution of tuber weights provided a good description of the general shape of the distribution and was used to generate estimates of the probability of given twinning frequences occurring by chance. For the detailed samples collected it was shown that the observed frequency of twinning was no greater than that obtained by chance.

(B. Marshall, H. T. Holverda[1], P. Struik[1])

Potato: thermal time and dormancy break [PU 5(h)]

For a period after harvest the buds of potato tubers will not sprout even when the tubers are stored in conditions that are later favourable for sprouting. The duration of that period of dormancy is variable, and experiments are investigating whether the development of tuber dormancy and its duration are related to thermal time.

Factorial treatments using cv. Maris Piper with three planting and three harvest dates produced tubers with nine different ages; chronological age and thermal-time from tuber initiation were not confounded. The tubers were stored at differing low temperatures for successively longer intervals before transfer to warm storage to induce sprouting. Dormancy break was recognised when sprouts reached 3 mm in length. Records made included time and thermal time to break of dormancy, size of tuber and numbers of sprouts.

Tubers transferred to 16°C at or soon after harvest took a long time to break dormancy and were extremely variable (65 and 115 days to first and to last tuber sprouting, respectively). The spread in times to dormancy break was reduced in tubers that were transferred to warm conditions later and also in tubers lifted at later harvests.

Most large immature tubers sprouted earlier than small ones, but sprouting was less uniform than for more mature tubers. The experiment is being repeated and is being analysed in terms of thermal time and normal time.

(D. K. L. MacKerron)

Potato: water stress, canopy expansion and crop growth [PU 5(i)]

The effects of water stress on the canopy expansion and growth of 21 genotypes was examined in an experiment in which plants were grown either with irrigation or droughted from plant emergence.

[1]Department of Field Crops and Grassland Science, University of Wageningen, The Netherlands

In the drought treatment, genotypes differed both in the maximum leaf area index (LAI) achieved and in the rate of canopy senescence. Both total dry matter accumulation and yield were correlated with LAI measured in mid-July.

Genotypes differed in the relation between the extension rate of individual leaves and soil moisture deficit. The solute potential of rehydrated leaves was measured as an indicator of osmotic adjustment in water-stressed leaves. Genotypes differed in the degree of osmotic adjustment with a maximum adjustment of 0.2 MPa in cv. Spunta. However, there was no significant correlation between the degree of osmotic adjustment and maximum LAI achieved in the drought treatment.

The kinetics of chlorophyll fluorescence were examined to assess photosynthetic performance. Constant yield fluorescence (Fo) was less in droughted than irrigated plants, but variable fluorescence (Fv) did not differ between treatments. In most cultivars, the ratio Fv/(Fo+Fv) was close to 0.83 in droughted plants, but significantly lower in irrigated plants. This suggests that photoinhibition was occurring in irrigated plants, but not in those which were droughted. However in cv. Ulster Sceptre, photoinhibition occurred in both irrigated and droughted plants. The rate of quenching of Fv did not differ significantly between treatments, indicating little effect of drought on carbon assimilation.

(R. A. Jefferies, D. K. L. MacKerron)

Potato: sucrose partitioning in source v sink tubers [PU 5(j)]

As tubers age they undergo a transition from a turgor-sensitive, starch synthesising tissue to a turgor-insensitive, non-starch synthesising tissue (*Ann. Rep. 1987*, 147). The role of assimilate supply in this transition was investigated. A single-stemmed population of potato plants was subjected to two treatments; the plants were either cut off at ground level (dehaulmed), or the tubers were detached from the stolons (detubered). The uptake and partitioning of sucrose into discs from such tubers was compared with that into discs isolated from untreated plants. The ability to synthesize starch was greatly reduced within 24 h of each treatment, the decrease being more pronounced in detubered (54%) than in dehaulmed plants (40%). Within 7 days, starch synthesis was reduced by 72% in both treatments. However, in marked contrast, the ability of isolated discs from these tubers to take up sucrose was unchanged until 7 days after treatment. The results demonstrate that the active uptake mechanism for sucrose and the ability of the storage cells to synthesis starch are independently regulated.

(K. M. Wright[1], K. J. Oparka)

[1]Short-term Appointment

Potato: apoplastic versus symplastic transport of Lucifer Yellow CH (LYCH) in the tuber [PU 5(j)]

The highly-fluorescent probe LYCH is a particularly effective membrane-impermeant probe for studying transport processes (Stewart, 1978; *Cell 14*, 741). LYCH was introduced into differentiating potato tubers, either by direct microinjection into the cytosol or into the apoplast via cuts made in the stolon cortex. Microinjected LYCH spread radially and rapidly via plasmodesmata and did not enter the cell wall or vacuole. However, LYCH which was transported into the tuber via the apoplast, entered the vacuoles of a range of cell types, including storage parenchyma. Since LYCH is unable to cross the plasmalemma the most likely pathway of the dye from the cell wall to the vacuole was by endocytosis, the molecule being transported in membrane-bound vesicles formed at the plasmalemma. Clathrin-coated vesicles were abundant in cells viewed by electron microscopy, providing a potential endocytotic pathway for dye movement. The results demonstrate a viable pathway for solute movement between the cell wall and the vacuole, which is frequently neglected in plant transport studies.

(K. J. Oparka, D. A. M. Prior)

Potato: turgor-sensitive sucrose partitioning in potato tubers [PU 5(j)]

Previous studies showed (*Ann. Rep. 1987*, 145) that the uptake of sucrose and its conversion to starch were acutely sensitive to changes in cell turgor within the storage parenchyma. In an attempt to isolate the effects of turgor on the uptake of sucrose at the plasmalemma from its potential effects on the intracellular partitioning of sucrose, storage discs were pulsed with [$^{14}$C] sucrose at a fixed cell turgor (approx. 80 kPa, the optimum for sucrose uptake and conversion). The discs were then transferred to a chase medium lacking radiolabel in which the turgor was manipulated using mannitol solutions (0-500 mol/m$^3$). Turgor effects were less pronounced following the uptake of sucrose than during uptake. However, a distinct turgor optimum (80 kPa) for starch synthesis remained when sucrose uptake at the plasmalemma was eliminated. A non-specific solute leakage occurred as the mannitol concentration was lowered from 300 to 0 mol/m$^3$. The data favour the view that the maximal stimulation of starch synthesis at low turgor (80 kPa) arises from a combination of increased active transport across the plasmalemma ('more pump') combined with decreased passive back-leak ('less leak').

(K. J. Oparka, K. M. Wright[1], D. A. M. Prior)

Potato: cell membrane permeability and membrane lipid and sterol composition as factors influencing susceptibility to calcium-related disorders [PU 5(m)]

Previous work demonstrated clear genotypic variation in the susceptibility of tubers to the calcium-related physiological disorder known as internal

[1]Short-term Appointment

rust spot (IRS), and evidence has accumulated to implicate changes in cellular compartmentation under restricted calcium supply as one of the causative factors. The fatty acid composition of the major phospho- and glycolipids has been studied, together with a detailed analysis of the sterol composition of steryl esters, steryl glycosides, acylated sterol glycosides and free sterol fractions. There was no evidence of substantial differences in the fatty acid composition of phosphatidyl ethanolamine, phosphatidyl choline, phosphatidyl inositol, monogalactosyl diglyceride and digalactosyl diglyceride lipids from IRS-resistant and IRS-susceptible genotypes. Qualitative and quantitative differences in sterol composition were also absent between the two genotypes compared (cv. Désirée — resistant: SCRI clone 10337de40-susceptible). However, total sterol levels were significantly higher in tubers of both genotypes when grown under a restricted supply of calcium. The sterols detected, in order of abundance, were ß-sitosterol, stigmasterol, cholesterol and campesterol. Combined gas chromatography — mass spectrometry showed that isofucosterol was a major component of the steryl glycoside and acylated steryl glycoside fractions and fucosterol an abundant component in the free sterol pool.

In parallel with analyses of membrane components, differences in membrane permeability between susceptible and non-susceptible genotypes were assessed. This involved preloading tuber discs with [U-$^{14}$C] sucrose and monitoring subsequent efflux. There was no overall correlation between the rate of efflux and the incidence of IRS.

(L. S. Talbot[1], H. V. Davies)

Potato: nuclear magnetic resonance (NMR) analysis of carbon transport across amyloplast membranes [PU 5(m)]

The extreme difficulty of isolating highly pure, intact and functional amyloplasts has prevented rapid progress in an understanding of the nature of compounds transported across the amyloplast membrane. NMR ($^{13}$C) techniques offer the possibility of determining which classes of compound are transported without the requirement for difficult isolation procedures. Potato tuber discs were prepared from actively growing tissues and incubated with either 300 mol/m$^3$ [1-$^{13}$C] glucose or [6-$^{13}$C] glucose. The 'outer shells' of the starch grain were digested with amyloglucosidase purified by fast protein liquid chromatography. This released high-specific activity $^{13}$C-glucose. The distribution of $^{13}$C between carbon positions 1 to 6 of the glucose molecule was then assessed on a Brucker AM 300-WB FT NMR using a 5 mm $^{13}$C/$^{1}$H dual probe. Very little randomisation (<5%) of $^{13}$C occurred between positions 1 and 6. Randomisation would indicate the enzymatic cleavage of $^{13}$C-fructose-1, 6-bisphosphate (derived from $^{13}$C-glucose) by aldolase and triose phosphate isomerase and implicate three-carbon compounds as the

[1]Short-term Appointment

principal products transported. The evidence therefore indicates that 6-carbon compounds enter the amyloplast to support starch biosynthesis.

(R. Viola[1], H. V. Davies, A. R. Chudeck[2])

Potato: the effect of sodium fluoride on glycolysis and starch biosynthesis in developing tubers [PU 5(m)]

Fluoride inhibited the rate of starch biosynthesis in tuber discs by 90% and increased the incorporation of [U-$^{14}$C] glucose into sucrose. Fluoride also stimulated a marked accumulation of 3-phosphoglycerate (3-PGA) and pyrophosphate (PPi). Substantial, but less pronounced, increases were recorded for fructose-1,6-bisphosphate (F-1,6-bisP) triose phosphate and hexose monophosphates. Fluoride decreased the concentration of fructose-2,6-bisphosphate (F-2,6-bisP), the activator of PPi-dependent phosphofructokinase.

An examination of the effects of 10 mol/m$^3$ fluoride on *in vitro* enzyme activities showed that enolase was inhibited by 90%. This explained the rapid increase in 3-PGA and decrease in pyruvate. The increase in 3-PGA is believed to be responsible for the fall in F-2,6-bisP content and the latter for the accumulation of triose phosphates and F-1,6-bisP. The well known inhibition of pyrophosphatases by fluoride is considered responsible for the accumulation of PPi. Furthermore, the assumption is made that PPi accumulation takes place in the amyloplast where an alkaline pyrophosphatase is located and where PPi is produced during starch biosynthesis. A substantial increase in PPi within the amyloplast would make starch biosynthesis thermodynamically impossible. The overall effect is a diversion of carbon into sucrose biosynthesis.

(R. Viola[1], H. V. Davies)

Potato: water stress and tuber carbohydrate composition [PU 5(m)]

The imposition of water stress in field grown potato plants decreased tuber growth rate and increased the concentration of starch and protein in tubers. No significant changes in the concentrations of these constituents occurred when tubers were subsequently stored for up to 42 d at either 3 or 10°C. By comparison, the principal tuber hexoses (glucose and fructose) increased substantially at 3 compared with 10°C, the concentration reaching a maximum of 17 mg/g fresh wt in unstressed tubers held at 3°C and 3 mg/g fresh wt in stressed tubers held at the same temperature. Differences in the extent of hexose accumulation between stressed and unstressed tubers were reflected in substantial differences in acid invertase activity between these treatments. However, these differences were only evident when enzyme extracts were rapidly vortexed to destroy an invertase/invertase-inhibitor complex. Invertase activity in some cases

[1]Research Student
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increases 75-fold following the destruction of the inhibitor. The patterns of change in sucrose content were more variable than those for the hexoses, but again there were significant effects of storage temperature and water stress. Degradation of previously stored sucrose could not account quantitatively for the observed increases in glucose and fructose.

(H. V. Davies, R. A. Jefferies)

Potato: glucose-6-phosphatase activity in tubers [PU 5(m)]

Protein extracts of potato tubers were probed in Western blots with monospecific antiserum raised to glucose-6-phosphatase purified from rat liver. Cross reactivity was demonstrated and the potato enzyme shown to have identical properties on SDS-PAGE as the mammalian enzyme i.e. the protein is a doublet, molecular weight 21 kDalton. Differential centrifugation also indicated that, as in mammals, the enzyme was enriched in microsomal pellets. The enzyme could not be detected immunologically in potato leaves and roots. However, Western blots did reveal immunological homology with protein from *Vicia* roots, barley roots, and from a range of fungi (*Phoma* spp., *Alternaria* spp., *Botrytis* spp., *Fusarium* spp.). This is the first unequivocal evidence of the existence of the enzyme in plants.

(H. V. Davies, A. Burchell[1])

Potato: the effects of tuber excision on hexose accumulation and invertase activity [PU 5(m)]

A marked increase in tuber hexose content and invertase activity occurs following the excision of tubers from the mother plant. This phenomenon was investigated further by comparing the responses of the cultivars Cara and Record and the SCRI clone 13737 1, genotypes known to differ in the extent of reducing sugar accumulation in storage. Tubers were excised at various stages in development to provide samples of different maturities. Total invertase activity (invertase inhibitor destroyed), basal activity (inhibitor present) and soluble carbohydrate composition were determined at excision and after storage for up to 16 d at 10°C. Hexose accumulation in storage was greatest in Cara, lowest in 13737 1 and intermediate in Record. Immature tubers accumulated more hexose in storage than mature tubers and, with few exceptions, the quantity of sucrose declined. Invertase activity (basal and total) increased markedly as hexose accumulation proceeded. Increases of up to eightfold occurred within 4 days after excision. Although an increase in total invertase activity always accompanied hexose production there was not a good quantitative relation between enzyme activity and the extent of hexose accumulation. The data suggest that the constitutive expression of invertase activity is tightly regulated through the attachment of the tuber to the mother plant. They further imply that increased invertase activity is the trigger which stimulates the

[1]Department of Medicine, Ninewells Hospital

substantial increases in reducing sugars on storage. However, it seems less likely that invertase activity alone controls tuber hexose content once the initial increase in reducing sugars has been established.

(D. L. Richardson, H. A. Ross, H. V. Davies)

Kinetics of Lucifer Yellow CH (LYCH) uptake into plant cell protoplasts [PU 5(o)]

The uptake kinetics of the dye LYCH were characterised in protoplasts isolated from leaves of *Nicotiana clevelandii,* and demonstrated a rapid initial phase (0-2 h) and a slower phase, linear between 2-5 h. At 25°C, uptake of LYCH, with respect to increasing substrate concentration, demonstrated biphasic kinetics, an apparent saturable component (0-1 mg/ ml LYCH) being superimposed on a linear component (1-10 mg/ml). At 0°C only the saturable component of uptake was present. The metabolic inhibitors CCCP and DNP did not significantly affect LYCH uptake but the plasmalemma ATPase inhibitor, sodium orthovanadate and the glycolytic inhibitor, 2-deoxy-D-glucose were both inhibitory. Uptake of LYCH was dependent on the pH of the medium, decreasing to insignificant levels as the pH was raised from 4.0 to 8.0. The majority of results are consistent with those obtained by other workers for the fluid-phase uptake of LYCH into animal cells and yeasts. The above results, and the physical properties of LYCH, are not consistent with a passive diffusion of the dye into the protoplasts, but other possible mechanisms (e.g. active transport) have not been excluded.

(K. M. Wright[1], K. J. Oparka)

Potato: genetic and environmental factors influencing tuber size distribution [PU 5(p)]

In collaboration with ADAS, research on the influence of seed size, cultivar and spacing on stem and daughter tuber production and yield was continued for a second season and at two additional locations to investigate the consistencies of a range of responses determining the development of tuber size distributions. The relation between the number of daughter tubers produced per unit ground area and the number of stems was asymptotic with little scatter, as in 1987. The relation between yield and stem density was more variable but again similar to that observed in the previous year. The precise variations between locations and between years are still to be quantified. Future work should focus on the relative effects of pre- and post-planting environments on stem and daughter tuber production.

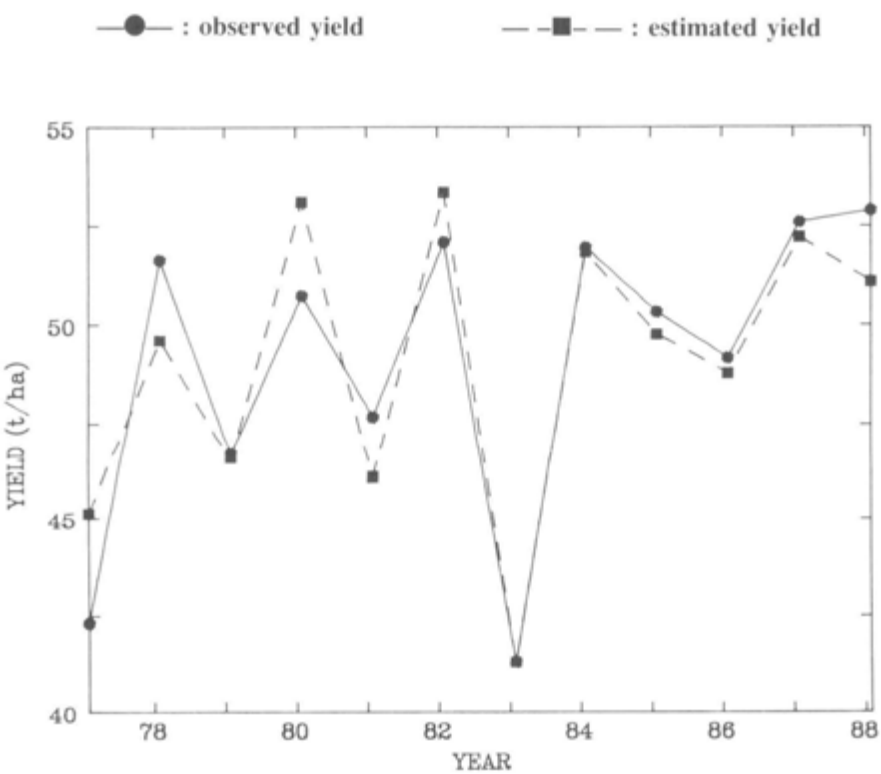
(B. Marshall, H. Taylor, C. Speller[2])

[1]Short-term Appointment
[2]ADAS, Leeds

Estimating the yield of the national potato crop [PU 5(q)]

Data from environmental physiology experiments on the potato crop were used to derive improved functions for use within the model of water-constrained growth and yield. Modifications were made to the functions used for the rate of canopy expansion, and water use, and in the calculation of dry matter concentration. An additional function was developed for the estimation of harvest index based on accumulated thermal time from emergence. These changes improved the performance of the model when applied to individual crops for both early and final harvests ($r^2 = 0.956$), and significantly improved estimation of the regional or national yields ($r = 0.871$). The model has the advantage of being mechanistic, and has been tested successfully for the whole country and over a wide range of types of growing season (1977-1988) (Fig. 1).

**Figure 1**




**Comparison between observed biological yield of the national potato crop (t/ha) for the years 1977 to 1988, and estimated yield, calculated using the model of water-constrained yield.**

Estimates of regional and national yields use single sets of data to represent conditions within large regions of the UK. This may be the principal source of the remaining 'error' and could be resolved by operating the model over more and smaller areas.

(T. D. Heilbronn[1], D. K. L. MacKerron, R. A. Jefferies)

Potato: genotypic differences in response to drought [PU 22(d)]

A range of 24 potato genotypes, representing as wide a range as possible of characters having implications for the water and carbon economy of the plant, were grown under three levels of water supply in a system that allowed almost complete recovery of the main roots. During growth, measurements were made to investigate the relations between stomatal conductivity (gs) and also relative water content (RWC) and irradiance and atmospheric humidity as modified by soil water supply.

Preliminary analysis of relations between gs and these principal environmental variables taken individually were disappointing in that none accounted for more than 71% of the variance (RWC in cv. Spunta) and most far less than 50%.

Rooting patterns differed widely between cultivars and between treatments, with significant interactions. The depth to 50% of root mass (D50) was less in dry soil than in wet soil for some cultivars e.g. Pentland Dell (56 and 64 cm) and Ulster Sceptre (32 and 54 cm). In others the water treatment did not affect D50 e.g. Pentland Crown (65 cm) and Cara (68 cm). In most cultivars the depth of 80% of root mass (D80) was less in dry soil than in wet e.g. Pentland Crown (93 and 100 cm) and Duke of York (65 and 70 cm), but in a few cases the pattern was reversed e.g. Cara (103 and 98 cm) and Maris Piper (100 and 97 cm).

(D. K. L. MacKerron, Peng Zhi-Yong[2])

## PROTEIN SEED CROPS

Field bean: cultivar evaluation [PU 18(a)]

The growth performance and suitability for production in a northern climate were assessed for twenty breeding lines and cultivars, including three of determinate habit, and four early maturing SCRI selections.

Due to cold wet weather in late March and early April a mean establishment of 37 plants/$m^2$ was lower than planned, and was lower than in any of the 3 years of the previous trial.

Dry weather in June checked plant height which was on average 38 cm less than in 1987, but ample rain in July and August allowed a good seed set and yields 30% higher on average than in 1987. Yields ranged from 6.4 t/ha in cv. Alfred to 3.7 t/ha in breeding line 684/925.

[1]Short-term Appointment
[2]Research Student

Harvesting was brought forward by dry sunny weather in September. The earliest maturing lines 684/925 and cv. Frauen 11-1 and those of determinate growth habit TP667 (cv. Piccolo) and cv. Tigo and also the conventional cv. Alfred lodged least in early August. However, by harvest time in September Tigo had lost some of its resistance to lodging.

Even in a season in which the period of maturation was shortened by dry weather at harvest time, three lines 684/925, Frauen 11-1 and ETS137/2/1 were about 18 days earlier in reaching maturity than the conventional cultivars Alfred and Maris Bead.

Three early maturing lines grown in isolation produced good yields of high quality seed as harvesting was completed during dry weather in September. These plots were of ETS 56/7/1 and also low and high trypsin inhibitor lines to be included in the 1989-1991 EEC Joint Faba Bean Test for nutritional quality.

(H. Taylor)

Field bean: modifications in carbon/nitrogen partitioning by nitrate [PU 18(a)]

Field-grown plants of cv. Maris Bead, fertilised with 0, (N0), 200 (N1) or 700 (N2) kg N/ha (Nitram), were analysed for carbon and nitrogen partitioning between vegetative and reproductive structures. N1 and N2 reduced the extent of nodulation substantially and, presumably through salt effects, checked growth in the early post-emergence period. However, by the end of the season pod dry weight in plants receiving combined sources of nitrogen out-yielded controls (N0) by 41% (N1) and 54% (N2), respectively. Increased yield appeared to result from enhanced growth of pods at nodes three and above. Shoot (stem + lamina) dry weights were also increased significantly by N fertiliser but less so than pod weights. Nitrogen application therefore improved harvest index. The percentages of flowers and pods aborted were not affected by nitrogen treatments. Nitrogen increased the percentage N content of reproductive structures (pods + seeds) early in the season but at final harvest differences in C:N ratios between treatments were extremely small.

(H. V. Davies, J. Sprent[1], A. Stanforth[1])

## FRUIT CROPS

Raspberry: pilot nutrient observation [PU 6(b)]

A small plantation of cv. Malling Jewel was planted in June 1985 into either UC compost or good gravelly loam soil.

During the 1987 and 1988 growing seasons two soil plots and one UC compost plot were freely irrigated and supplied weekly with 11.1 kg/ha N, 3.4 kg/ha P and 1.2 kg/ha K, in addition to an overall standard application

[1]Biological Sciences Department, University of Dundee

of fertiliser applied in March each year. Thus the three treated plots received totals of 210 kg/ha N, 79 kg/ha P and 53 kg/ha K each year and the controls received 77 kg/ha N, 38.5 kg/ha P and 38.5 kg/ha K.

Irrigation and additional nutrition improved the numbers and lengths of canes produced in 1987 and their fruiting performance in 1988 (Table 1).

**Table 1. Effects of irrigation and added nutrition on fruiting cane performance, 1988**

| | *Soil* | | *UC compost* | |
|---|---|---|---|---|
| | Irrigation and extra nutrients | Control | Irrigation and extra nutrients | Control |
| Mean cane number/stool | 7.2 | 6.5 | 7.4 | 6.6 |
| Mean cane length (m) | 1.82 | 1.71 | 1.74 | 1.57 |
| Mean weight/berry (g) | 3.20 | 2.70 | 2.91 | 2.19 |
| Mean yield/ha (t) | 15.8 | 9.8 | 11.7 | 7.5 |

Fruit production by plants grown in UC compost was inferior to that of plants grown in this particular soil, regardless of the water and nutrient inputs.

The beneficial effects of the relatively high levels of additional water and nutrient application suggest the need for a reappraisal of the nutrition and irrigation requirements of raspberry plantations.

(M. R. Cormack)

Raspberry: mechanical harvesting [PU 6(c)]

In 1988 the final comparison was made in an experiment evaluating hand picking against machine picking with the Littau harvester.

Hand pickers collected 6.4 t/ha from cv. Malling Jewel, 7.0 t/ha from cv. Glen Prosen, 5.5 t/ha from 33R40 and 7.4 t/ha from 14/106. Equivalent machine picks collected 2.9 t/ha, 3.5 t/ha, 3.0 t/ha and 3.6 t/ha of ripe fruit. Thus the machine harvested approximately 50% of the ripe fruit collected by hand. This percentage is low by comparison with previous data which indicate that the machine should pick about 70% of a hand pick. Wind (see Report p. 199) was probably responsible as the machine leaves behind on the plants more 'ripe' fruit which is liable to be blown off or damaged. Also the machine cannot pick a row which is leaning over due to broken posts or wires, without causing further damage.

The mean weight of ripe berries picked by machine was about 5% heavier than that of hand picked berries, a reflection of the greater maturity of machine picked fruit.

The selection 14/106 was once again shown to be superior in terms of discrimination. Only 1.7% by weight was collected as under-ripe compared

to 5.0% from Malling Jewel, 11.2% from Glen Prosen and 10.0% from 33R40; 2.1% of ripe fruit with plug attached was collected from 14/106 compared to 9.6, 6.4 and 7.6% respectively from the others. Also fewer broken laterals appeared in the samples of 14/106.

For the second time fully biennial treatments in a plantation of 14/106 established in 1983 were picked by hand and by machine and each compared with hand picked annual cropping. Primocane growth in the fruiting biennial plots was removed by hand when it reached about 15 cm in height. Hand picked ripe fruit from biennial plots cropped at 7.9 t/ha, machine picked biennial plots at 7.3 t/ha and the hand picked annual plots at 4.5 t/ha. These yields are smaller than those reported last year, probably because of losses caused by the high winds in mid-season (see Report p. 199). This trial was even more exposed to these winds than the trial reported immediately above. Breeder's selections are screened for suitability for machine harvesting in single row plots. Best discrimination was recorded in 14/106, but 7515C5 and 7826C1 showed initial promise.

(M. R. Cormack)

Raspberry: National Fruit Trials [PU 6(d)]

Two First Stage Trials, which are the first independent assessments of breeders' selections, are currently in progress at SCRI, one planted in 1984 and one in 1986. The first produced its third and penultimate full crop in 1988 and the second its first full crop.

In 1987 yields in the trial planted in 1984 were affected by double dart moth damage. In 1988 the most serious damage was caused by high winds; considerable damage was caused to the early ripening fruit and some lateral breakage occurred on July 11 but most harm was done by a severe gale on July 25 which blew all day with gusts ranging from 52 to 95 km/h.

In common with many commercial plantations, picking had been hampered by wet weather and consequently a heavy crop of well ripened fruit was present on the plants at the time the gale struck. Much of this fruit was shaken off or severely damaged.

Cultivars with vigorous and upright primocanes suffered most damage as tops were more exposed above the level of fruiting cane. Late ripening cultivars suffered greater losses than the early cultivars, since green as well as ripe fruit and laterals suffered injury. The 3655 series and cv. Leo from IHR (East Malling) are upright, vigorous and late, and were particularly badly affected. Leo yielded 8 t/ha, 3655/48 10t/ha and 3655/47 12 t/ha. The heaviest yield of 19 t/ha was produced by 7816C6. 7515C5 yielded 15 t/ha as did 7518C6 which also produced the largest fruit (mean 5.97 g) in a year in which fruit size was generally good. Standard cultivars Glen Moy and Glen Clova produced 15 and 14 t/ha respectively.

The wide range of yields (from 2.8 t/ha from 795F7 to 14.6 t/ha from 8044C9) in the trial planted in 1986 is mainly a reflection of variable

establishment. Exceptionally large fruit with a mean weight of 6.38 g was borne by the selection 8044C9. 14/106 yielded 10 t/ha of fruit with berries averaging 3.56 g in weight. This fruit size was similar to that of berries of cultivars Leo and Glen Clova, which yielded 7 and 5 t/ha respectively.

(M. R. Cormack)

Raspberry: manipulation of vegetative and fruiting phases [PU 6(d)]

The search for alternative methods of regulating cane vigour in raspberry continues. Comparison of a range of heat intensities and timings of propane gas flame treatment has shown that young canes require treatment at between 5 and 10 cm in height for efficient desiccation at calorific inputs which will not harm the fruiting canes. This is considerably earlier than the former conventional treatment stage (10-20 cm) using dinoseb, and has several drawbacks, including a very narrow application 'window', the incomplete emergence of the first flush by that time, and the relatively small reduction in cane vigour which is achieved. Repeat treatment is not possible because of injury caused to fruiting canes.

Simultaneous application of flame treatment to both sides of the cane row gave more effective desiccation than application to one side at a time using the same total output. If suitable application equipment were developed, cane desiccation using propane gas flame treatment might be of interest as a stop-gap solution to excessive cane vigour: it is not subject to pesticide legislation. In collaboration with British Oxygen Company, acetylene gas burning in a stream of compressed air using various burner heads was compared with propane gas burning in ambient air conditions. Desiccation of young canes with acetylene was less efficient than with propane.

Evaluation of liquid nitrogen for desiccation of plants by freezing showed that the maintenance of a low temperature for the length of time necessary to achieve adequate cell disruption of green tissues was impracticable under field conditions.

Further evaluation of a range of sulphuric acid concentrations showed that the margin of safety between effective desiccation of young canes and unacceptable injury to fruiting canes was very narrow, particularly with high volume application. The addition of wetter to the spray solution increased both the efficiency of desiccation and the adverse effects on fruiting canes, giving no improvement in margin of safety. There was evidence from several trials that replacement cane growth also responded adversely to higher concentrations and volumes of acid. Laboratory tests using a wide range of possible barrier treatments for protection of the fruiting cane against injury by sulphuric acid showed no beneficial effects. These results, together with the handling hazards associated with sulphuric treatment and its corrosive effects on spraying equipment and raspberry wires, suggest that this chemical should be considered further only if no alternative treatment can be found.

Promising results were obtained in 1988 screening trials with sodium monochloracetate (with added wetter) and with fomesafen. Ammonium tetraformate was ineffective as a cane desiccant as were low rates of application of sodium chlorate.

(H. M. Lawson, J. S. Wiseman)

Raspberry: time lapse video studies [PU 9(b)]

A system has been developed to examine the feeding behaviour of the clay-coloured weevil, *Otiorynchus singularis* in the dark. An infra-red sensitive video camera used in conjunction with infra-red diode sources, illuminated the weevils feeding on raspberry primocanes with non-visible radiation i.e. at wavelengths greater than 800 nm. A time lapse video recorder monitored the activity at 1 second intervals over an extended period. A marked weevil was observed feeding over a period of 30 hours. During this time it fed for a total of 4.7 hours; the remainder of the time was spent searching or in a quiescent state. The sequence of damage began with intensive gnawing at a site immediately below the apical region, leading to total severance of the shoot tip.

Damaged raspberry foliage may have the ability to deter weevils from feeding by releasing some repellant or anti-feeding compound, such as tannins or phenolics. The above video technique was adapted to observe weevils feeding on raspberry foliage in a *choice* chamber by using infra-red backlighting to silhouette the weevils under damaged or undamaged raspberry leaves. It appears that the clay-coloured weevils' initial reaction to damaged leaves is one of repulsion. Fewer weevils approached the damaged leaf and did so more slowly than they did the undamaged foliage, where they spent most of their time.

(D. C. Gordon, S. C. Gordon[1])

Blackberry and novel fruit crops [PU 6(d)]

In single row observation plots of blackberry and hybrid Rubus cultivars and selections, the blackberries Bedford Giant (23 t/ha) and Ashton Cross (19 t/ha) continued greatly to outyield all others. Tayberry produced about 7 t/ha, Loch Ness (the new spine-free blackberry from SCRI) about 6 t/ha, Tummelberry about 5 t/ha and Sunberry about 4 t/ha. These plots are situated in the lea of a mature windbreak and suffered little of the wind damage that affected other trials.

In a biennial cropping trial planted in 1985, part-biennial Ashton Cross (19.0 t/ha) outyielded annual (14.5 t/ha). Part-biennial Tayberry produced 5 t/ha compared with 4.3 t/ha from annual cropping plots.

Amongst novel fruit crops which are being assessed are *Hippophae rhamnoides, Vaccinium* spp., *Sorbus* spp., *Aronia* spp., *Rosa* spp. and *Amelanchier alnifolia.*

(M. R. Cormack)

[1]Zoology Department

Highbush blueberry [PU 6(d)]

The high winds in July which caused so much damage to the raspberry crop were also detrimental to blueberries. A long established trial had been pruned for the first time in several years and a yield reduction was expected, but the wind broke branches, and blew off approximately half the crop. Nevertheless the beneficial effects of irrigation were still apparent and compared with non-irrigation the yields for the larger bushes of the cultivar Berkeley were 5.7 to 3.1 t/ha, and Bluecrop 3.8 to 2.3 t/ha, respectively. Fruit size was improved by irrigation.

Some 700 selections from the USDA breeding programme and 14 American cultivars have been planted out for evaluation.

(M. R. Cormack)

## ROOT AND SOIL INVESTIGATIONS

An analysis of the fractal properties of branching structures [PU 22(a)]

Studies to quantify the branching topology of complex biological structures such as roots and trees showed that tree branching patterns may be understood in terms of a fractal description, where a multiplicity of scales contribute to the diversity of form observed within each generation. Certain elements of this description are conserved within a given species, while others are modified by environmental conditions. This underlying simplicity and order which defines the structure may be a reflection of the genetic algorithm employed, but still allows for considerable adaptability of a given species to its environment. The analysis is currently being applied to root systems.

(J. W. Crawford, I. M. Young)

Soil solution dynamics [PU 22(b)]

Crops obtain their nutrients by uptake from the soil solution. The application of fertilisers to soil inevitably results in massive changes in soil solution composition. There are not only direct effects resulting from the dissolution of the fertiliser but also indirect effects resulting from the interaction of the fertiliser constituents with the soil matrix and further interactions with the soil microflora. In a laboratory experiment the addition of ammonium nitrate to soil, at a rate comparable with that used in a potato fertiliser applications resulted in a three- to fivefold increase in the concentrations in the soil solution of potassium, magnesium and calcium. These nutrients were displaced by ammonium from exchange sites in the soil matrix. A similar result was obtained in a field experiment with potato where soil solution concentrations in the root zone were monitored through the growing season. Initially, major nutrient concentrations were high but decreased rapidly through the early part of the growing season. It seems likely that much of the depletion of nitrate from the soil solution

results from its incorporation into the microbial biomass and that this results in a concomitant decrease in nutrient cations which are the counter-ions for nitrate. In this experiment the concentration of calcium, the main counter-ion, was diminished to less than 2.0 mol/$m^3$. Such a depression might be involved in the physiological disorders of the potato thought to be related to calcium nutrition. Internal rust spot of the tuber is such a disorder but was not observed in this experiment.

(D. J. Linehan)

Physiological compensation for non-uniform nutrient supplies [PU 22(c)]

The ultimate extent to which a local increase in nutrient inflow rate (*Ann. Rep. 1987*, 157) could compensate for a non-uniform nutrient supply has been examined theoretically. In the right circumstances, such an increase could meet a plant's nutrient demand for substantial periods of time (i.e. >1 day): the higher the demand and rooting density, the more transient the duration of full compensation; the more immobile and sparsely available the ion, the lower the nutrient demand that can be satisfied over a given interval of time (Table 2).

The high nutrient demands of arable crops and weeds suggest that local increases in ion inflow rate can act as a mechanism to compensate for severely non-uniform supplies only when these occur in concert with morphological changes such as adjustments in root:shoot ratio and root branching patterns. In slower-growing plants, or when the non-uniformity is not serious, the purely physiological response of increased inflow rate could be an important means of buffering plant growth.

(D. Robinson)

**Table 2. Maximum possible durations of full compensation for a non-uniform nutrient supply by means of a local increase in inflow rate.**

| | Nitrate | Potassium | Phosphate |
|---|---|---|---|
| Nutrient demand (pmol/m.s) | 100 | 10 | 0.001 |
| Rooting density (km/$m^3$) | | | |
| 10 | 220d | 23d | > 1 yr |
| 100 | 43d | 5d | > 1 yr |
| 1000 | 10d | 2d | 102d |

Morphological compensation for non-uniform nutrient supplies [PU 22(c)]

Classical experiments (*New Phytologist 75*, 479) showed that when only parts of the seminal roots of barley plants are supplied with nitrate or phosphate, the production of lateral roots is abundant in those regions but suppressed elsewhere. This was thought to be a key feature of plants permitting them to compensate for non-uniformities in nutrient availability.

Using a simple model of an 'optimal' root system (*Ann. Rep. 1987*, 157), the data have been re-examined to assess more precisely the extent to which the localised growth of a root system could act as a compensatory mechanism. The localised production of lateral roots in the experiments was found to involve a high degree of 'redundancy', that is, inter-root competition, in response to a localised supply of nitrate. Moreover, the production of redundant roots was matched closely by the extent to which the plant's shoot growth fell short of that of control plants receiving a uniformly high supply of nitrate, suggesting perhaps that assimilate was diverted into the production of apparently useless roots at the expense of shoot growth. In response to the more immobile phosphate ion, however, the production of lateral roots was almost exactly 'optimal' as predicted by the model: there was no redundancy, and shoot growth was the same as in the control plants. The important question of why root systems respond in this way in response to nitrate ions will be the subject of future work.

(D. Robinson)

Impact of roots on nitrogen mineralisation in the rhizosphere [PU 22(c)]

Collaboratively, a theoretical model has been developed describing the quantitative relations between some of the key processes involved in nitrogen mineralisation. Of particular interest is the effect that root-derived carbon can have on the production of plant- available nitrogen, the amounts of such nitrogen that could be made available to a root, and the role in mineralisation of predators of bacteria such as protozoa and nematodes (*Ann. Rep. 1987*, 120).

The release of soluble carbon compounds from a root was assumed to occur by one of two processes: cortical cell death or exudation from intact cells. On the basis of assumptions chosen to maximise the amount of mineralisation, greater amounts of net mineralisation are possible at realistic soil C:N ratios if the bacteria are grazed than if they are not. More mineralisation occurs when the substrate released from the root has a high C:N ratio (as in cell death) than when it is relatively nitrogen-rich. The amounts of nitrogen that a single root might cause to be mineralised are unlikely to account entirely for the high rates of nitrate inflow that have been measured experimentally for many crops receiving nitrogen in the form of fertilisers. However, if the C:N ratio of the soil is greater than 20:1, the loss of some carbon from a root is essential if any mineralisation is to occur. Any such effect is likely to be located close to the root surface.

(D. Robinson, B. S. Griffiths[1], K. Ritz[2], R. Wheatley[2])

Uptake of Lucifer Yellow CH (LYCH) into intact barley roots [PU 5(o)]

Intact seminal roots of barley were shown to take up and retain LYCH in their vacuoles. When the root tip was dipped into a 1% (w/v) solution of

[1]Zoology Department
[2]Mycology and Bacteriology Department

LYCH, differentiating and dividing cells showed, following fixation and embedding, a prolific uptake into provacuoles, the dye becoming bound to electron-dense material within the vacuole. The dye freely entered the apoplast of roots in which the Casparian band was not developed and was taken up into vacuoles in both the cortex and stele. However, when LYCH was applied to a 1 cm band of root, approx. 6 cm behind the root apex, the dye was completely prevented from entering the stele, only the cell walls and vacuoles of cortical cells taking up LYCH. The inability of LYCH to cross the plasmalemma of the endodermal cells and enter the stele via the symplast substantiated previous reports that the dye is membrane-impermeant. A calculation of the energetic requirements for LYCH uptake supported the contention that LYCH enters the vacuoles of plant cells by a process that resembles fluid-phase endocytosis.

(K. J. Oparka, D. Robinson, D. A. M. Prior, P. Derrick[1], K. M. Wright[1])

## WEED AND HERBICIDE INVESTIGATIONS

### Weed seedbanks [PU 23(c)]

A joint project with IACR (Long Ashton Research Station), ESCA, ADAS and Queen's University, Belfast is examining the short- and long-term implications of reduced herbicide inputs in cereal rotations. At SCRI, soil samples from a series of field experiments carried out in England, Scotland and Northern Ireland have been analysed for weed seed content. These data provide the base from which the effects on the soil seedbank of different weed control strategies can be assessed. Seedbank data are also being compared with quadrat counts of emerged weed seedlings at all sites in order to assess the predictability of presence or absence of important species.

In a related series of experiments, the persistence over several years of seeds from pure stands of eight weed species is being monitored in successive winter wheat crops. Seedbank records are again being compared with seedling counts in the field.

Comparison of hand-sieving against mechanical shaking and sieving (using a Fritsch Analysette) for extraction of weed seeds from soil samples showed that the two techniques were equally efficient in extracting seeds and had no significant effect on the germination of seeds recovered. However, the mechanical system offered advantages in saving of time and consistency of performance.

(H. M. Lawson, G. McN. Wright)

### Weed control — information technology [PU 23(c)]

The HERBREX data-base was extended to include amenity grassland weed control. Its structure was modified to permit easy transmission of

[1]Short-term Appointment

data to the MICROBIRD program for inclusion in problem-solving advisory packages. The first package on cereal and grassland weed control, called MICROHERB, has been well received by DANI advisers. Further packages are being developed in cooperation with DANI and Queen's University, Belfast.

Programs have been devised which will permit the extension of the weed data in HERBREX to include growth stages at which individual species are susceptible to herbicides.

(H. M. Lawson, G. McN. Wright, P. Smith[1])

Contamination of seed potato crops by herbicides [PU 5(n)]

Stored tubers from plots where cv. Maris Piper was treated at 40% canopy closure with 10% of the normal application rates for spring barley of metsulfuron-methyl (0.6 g a.i./ha) or a formulated mixture of thiameturon-methyl and metsulfuron-methyl (4.1 g + 0.4 g a.i./ha) showed no adverse effects on storage quality or chitting behaviour in comparison with tubers from untreated plots. However, where tubers from plots treated with the formulated mixture were grown on in pots, yield of daughter tubers was 13% less than that from tubers of similar size selected from untreated plots. These results indicate that the residual effects of accidental contamination of seed crops by sulphonylurea herbicides require further investigation.

(J. S. Wiseman, H. M. Lawson)

[1]Data Processing Department

# CHEMISTRY

M. J. ALLISON

During the year chemical determinations included SMCO in brassica (1,540 samples), thiocyanates in brassica (480 samples), individual glucosinolates in brassica (600 samples), digestibility of brassica (876 samples) reducing sugars in swede (160 samples), micromalted samples of barley (1,140 samples), small-scale tests on barley breeding lines (800 samples), total glycoalkaloid content of potato tubers (330 samples), individual sugars in potato tubers (900 samples), elemental analysis (400 plant and soil samples) and stable isotope analysis (1,844 $^{15}N$ samples and 46 $^{13}C$ samples).

In the autumn our NIR software package was completed, and a contract was signed with Pacific Scientific Ltd., which included an agreement to market the software package on a world-wide basis. Apart from the financial benefits of royalties, there will be considerable scientific advantages as Pacific Scientific are in the forefront of NIR research. The HPLC capacity of the Department was more than trebled this year by the acquisition of an isocratic system with autosampler and an autoprep system. The recently acquired GC Mass spectrometer, the plasma emission spectrometer and the stable isotope mass spectrometer were all commissioned this year.

Work with other institutes included the detection of mite damage in stored cereals in collaborative experiments with the MAFF Stored Products Laboratory in Slough. This work potentially could be extended to the detection of insect damage in stored products. Studies on the biochemical basis of milling energy have continued in collaboration with different maltsters. The Department has also been a scientific co-partner in an IFS project with ESCA on the biochemical basis of crisping quality in potatoes and, similarly has involvement in an IFS project with NSCA on the effects of environment on glucosinolates in oilseed rape seed.

## Estimation of the sugar content in potato tubers [PU 1(f)]

A high content of reducing sugars in potato tubers results in poor crisping quality (crisps have an unacceptable dark brown colour). In a comparison of techniques to estimate reducing sugars in tubers, 50 samples evenly spread over the range 1 to 7 g total sugar per 100 g dry weight were analysed by

1. An HPLC method
2. An enzymic autoanalyser method
3. An autoanalyser method with neocuproine detection.

Highly significant correlations ($P < 0.001$) were obtained from the results of these analyses.

| | | r value | b value |
|---|---|---|---|
| HPLC | v enzymic total sugars | 0.959 | 0.92 |
| HPLC | v enzymic reducing sugars | 0.983 | 0.77 |
| Neocuproine | v HPLC reducing sugars | 0.984 | 0.88 |
| Neocuproine | v enzymic reducing sugars | 0.988 | 0.86 |

The HPLC method is preferred to the more expensive enzymic methods, and is currently used by the Department to estimate the individual sugars (fructose, glucose and sucrose). However it is evident from the above correlations that the simple, rapid autoanalyser method using neocuproine could be used to screen large numbers of samples for reducing sugar content.

(H. Bain, D. Richardson[1])

Separation methods for useful biochemical markers in barley [PU 2(c)]

Following previous successful SDS-gel electrophoretic separations of storage proteins, work was continued on both storage protein and soluble protein separations by HPLC.

It was established that field inversion pulsed electrophoresis was limited to DNA fragments less than 1 megabase in size. Thus angled pulsed field separations appear to be the method of choice for the separation of larger fragments (1 to 12 megabases in size). Such a pulsed system in combination with 'rare-cutting' restriction endonucleases may provide an optimum resolution system for the separation of large DNA fragments which may aid subsequent studies on DNA polymorphisms.

(M. J. Allison)

The use of milling energy to monitor the malting process [PU 2(f)]

As barley grains germinate the internal structure is modified and the grain becomes softer. The best modified malts may therefore be ascertained by comparing relative hardness, using the milling energy test (*Ann. Rep. 1987*, 56-57). The test is being used on an experimental basis to monitor the rate of endosperm modification of different cultivars during the malting process. It is much quicker than previously existing malt modification tests and provides excellent predictions of the hot water extracts which can be obtained at any stage of the germination phase. This technique can provide the barley breeder with more complete information regarding malting characteristics of cultivars. It will also be useful to the maltster wishing to determine either the optimum malting cycle for a sample, or which different samples may be malted together.

[1]Physiology and Crop Production Department

The rates of water uptake and initial germination have been suggested as important factors in determining malting quality, being influenced by genotype and by the steeping regime employed during malting. Experiments with four steeping regimes confirm differences due to genotypes and to steeping regimes and also show significant genotype × steeping regime interaction for certain important malting attributes, including hot water extract. Water uptake proves to be a useful indicator of the optimum steeping regime for a given cultivar but differences between cultivars are not reflected in differences in other malting characters. Germination rate can be used to predict malting quality only if the range between cultivars is large. Over a narrower range, the milling energy test, applied following steeping and only 1 day's germination, will predict the hot water extracts obtainable at the completion of malting.

(K. Taylor, J. S. Swanston[1])

Development of a commercial software package [PU 2(h)]

The principal components package 'Prospector' (*Ann. Rep. 1987*, 167) was rewritten within a commercial software package for near infra-red spectrophotometers marketed by Pacific Scientific Inc. of Silver Spring, Maryland, USA. The completed PCA package, comprising some 35 programs, now provides a 'user friendly' environment for the analysis of visible and near infra-red spectra, runs twice as fast as Prospector and includes many new features. The PCA package is to be launched commercially in the autumn of 1989.

(I. A. Cowe, D. C. Cuthbertson, J. W. McNicol[2])

Toxic constituents of brassica [PU 4(1)]

Collaborative research has been primarily focussed on the two major toxic factors, SMCO and glucosinolates. Preliminary results of investigations to determine the relationship between the concentration and composition of glucosinolates in different plant parts suggest that very low glucosinolate seed cultivars (< 20 $\mu$M/g) produce both stems and leaves with slightly lower total glucosinolate contents than those from very high glucosinolate seed cultivars (> 100 $\mu$M/g). However these differences were considerably less than those found between the seeds of different cultivars, with observed variation of less than 15 $\mu$M/g and 6 $\mu$M/g for the stem and leaves, respectively. No clear relationship appeared to emerge between concentrations of individual glucosinolates in the various plant parts.

In view of the possible adverse effects on wild animals of browsing over-wintering oilseed rape, the levels of SMCO were estimated in both forage and oilseed rape cultivars over the critical winter period. There were significant differences in the concentrations of this potentially toxic amino

[1]Cereal and Legume Genetics Department
[2]SASS

acid, particularly during the period January to March. In these months the low glucosinolate cultivar Ariana had a significantly higher concentration of SMCO than either a single low cultivar of oilseed rape, or two forage rape cultivars. However, by April these differences had almost disappeared, although the mean levels of SMCO in all the cultivars were almost double those as determined at the beginning of the trial in the previous autumn.

(D. W. Griffiths)

GC mass spectrometry, stable isotope mass spectrometry and elemental analyses

Much time was occupied with installing, commissioning and testing a new Kratos 8/90 organic mass spectrometer, a Europa Scientific stable isotope mass spectrometer and a ARL 3510 inductively coupled plasma spectrometer. After initial environmental problems each of the instruments has been calibrated with recognised standards.

(M. J. Allison)

Organic mass spectrometry

A variety of samples were run on the instrument mainly using capillary gas chromatography for sample introduction. (Electron impact ionisation was employed allowing library searches of 43,000 spectra for the purposes of identification.) In collaboration with the Food Science Division of the University of Strathclyde, the mass spectra of some 70 compounds associated with raspberry flavour were determined. These appeared to be mainly terpenoid in nature.

In analytical work within the institute fatty acid methyl esters and TMS derivatives of sterols found in potato tubers have been characterised. Metabolic profiling using a capillary gas chromatograph together with solvent dissolution of the leaf surface was employed isolate to compounds implicated in aphid interaction with raspberries, and several of these compounds have now been identified. During the course of a BTG funded project on naturally occurring nematicidal compounds, a suite of chemicals exhibiting these properties have been isolated and identified in conjunction with University of Salford Chemistry Department.

(G. W. Robertson)

Stable isotope mass spectrometry

Some 1500 samples of mainly barley and wheat were analysed for $^{15}N$ and %N content. Facilities for $^{13}C$ analysis were developed with standards provided by SURRC East Kilbride. Using graphite and corn oil standards, delta V.S. PDB values were determined for 'in house' standards of glucose and potato tubers for routine laboratory analysis.

Analysis provided for the University of Dundee included samples of fresh water and marine sediments for $^{15}N$ and $^{13}C$ content, (Department of Geological Sciences) and $^{15}N$ analysis on 260 rice field samples (Department of Biological Sciences). In an inter-laboratory trial in conjunction with the International Atomic Energy Agency in Vienna the unit provided data on international standards for $^{15}N$ and $^{13}C$.

(G. W. Robertson, W. M. Stein)

Inductively coupled plasma emission spectrometry

This year an average of 10 different elements were determined in each of 418 samples of plants, soil and nutrient solutions. Elements determined included Ca, Mg, Na & K as macronutrients and Al, Ba, Cu, Co, Fe, Mn, Mo, Pb, S, Sr and Zn as micronutrients.

(W. Matheson)

# DATA PROCESSING

R. J. CLARK

Early in the year the Department moved into a purpose built suite in the newly opened Sanderson Building. Suspended flooring ensures flexibility in positioning equipment, air conditioning is provided, and the electricity voltage is stabilised. All the staff now work at the Mylnefield site.

The provision of services is continually being reassessed: support for graphics has increased, less emphasis is given to data entry; and training has become a high priority because of the increasing number of scientific staff and the changes due to the installation of more IBM compatible personal computers (PC's). All scientific departments buy PC's from their own budgets but data processing staff advise on purchases to ensure standardisation and the selection of appropriate equipment, provide training and ensure uniformity of software. Throughout the site there are about 35 IBM compatible micros with the remainder being Apricot F series, Xen and BBC B and Masters.

Mainframe usage by SCRI, as measured by logons, reduced by over 16% compared to the previous year (Table 1), due to the transfer of work to microcomputers. However, the number of registered EMAS users rose by 11%, perhaps due to the increased use of the electronic mail services provided through EMAS and the Minitab statistical package following training provided by SASS.

**Table 1. Mainframe usage 1988**

| *Department* | *No. of User Processes* | *Jobs* | *% of Total* |
|---|---|---|---|
| Administration | 1 | 2 | 0.0 |
| Brassica Genetics | 6 | 234 | 3.0 |
| Cereal and Legume Genetics | 7 | 792 | 10.2 |
| Chemistry | 7 | 135 | 1.7 |
| Data Processing | 9 | 1299 | 16.7 |
| Estate | 1 | 38 | 0.5 |
| Information Services | 2 | 298 | 3.8 |
| Mycology and Bacteriology | 11 | 477 | 6.1 |
| Physiology and Crop Production | 26 | 1673 | 21.6 |
| Potato Genetics | 11 | 1368 | 17.6 |
| SASS | 2 | 313 | 4.0 |
| Soft Fruit Genetics | 3 | 91 | 1.2 |
| Tissue Culture | 2 | 37 | 0.5 |
| Virology | 10 | 385 | 5.0 |
| Zoology | 14 | 621 | 8.0 |
| Total | 112 | 7763 | 100.0 |

Planning for the future must take account of changes in the central services announced by the Edinburgh University Computing Service when discontinuance of the present EMAS system sometime after 1990 is likely to entail considerable re-training for scientists at SCRI.

A third Camtec PAD was leased to give additional communications lines to access the Edinburgh Network for mainframe computing services. Two PADS are housed in the Computer room connected by linedriver to one in the Hughes building where the British Telecom (BT) line terminates.

## Hardware

An IBM PS/2 Model 60 was borrowed from the Potato Genetics Department to enable work to continue on the CHIP program, following the departure of the originator.

Both the Apricot Xi micros in the Department were upgraded to IBM 80286 AT compatibility. A Dell AT compatible with a maths co-processor and EGA monitor was installed for running large application packages like Supercalc.

## Software

Software for specific applications is written in-house when required, with specially selected commercial software packages approved for more general use, particularly spreadsheets, databases and graphics programs.

The in-house programming included work on CHIP. Some options that had not proved feasible were removed from the mainframe version and more cross checking was added, and in the PC version work continued to try to fit it on a standard PC running Microsoft Fortran.

The 'C' programming language version from the same software house was investigated as a possible replacement for Pascal, particularly if UNIX becomes the preferred operating system in the future. Pascal, however was the chosen language for an application for enzymic determination of sugars directly from spectrophotometer plotter output using a proprietary A/D converter and an IBM interfacing card. This system replaced the former method of hand measurement of plotter rolls.

The Comparamill program was enhanced by the addition of an Epson HX20 program connected simultaneously to a balance to acquire sample weights in a suitable format.

The Potato Seedrate program written by B. Marshall[1] was extended to include some graphical display and a user friendly front end.

Sometimes the distinction between commercial and in-house programs is blurred by their application. For example, Supercalc was used with macros written in-house to provide a template for a pseudo 'expert system'. It summarised herbicide susceptibility and growth stage ratings for a combination of weed species and herbicides. Supercalc Version 4 provided

an easy upgrade path from the earlier Apricot version with the added attraction of integrated graphics, and it will continue to be the recommended spreadsheet package for IBM compatibles.

Simplified procedures were introduced to enable the library staff to request loans from the British Library using a commercial software program 'Headline', on-line through EDNET. An inexpensive commercial integrated package, Microsoft 'Works', was investigated as a simple entry level package to meet most needs on a PC.

(R. Kidger, I. Black, S. Clark)

## Image Analysis

Novel applications continue to arise for quantitative measurements made directly from a photograph, microscope slide or drawing. The semi-automatic method acquires the image from a digitising tablet connected to a microcomputer, and the fully automatic, from a television camera forming part of a Quantimet 900 image analyser. Training was provided for new members of staff in the use of existing programs for digitising virus and nucleic acid particles from electron micrographs.

Applications for image analysis under collaborative development with science departments include: estimation of volume and biomass of individual soil micro-organisms by segmentation into horizontal strips for studies of soil productivity; estimation of projected area, length and volume of root vegetables for studies of crop size distribution; quantifying size and shape of barley grains to investigate a possible relationship with differences in milling energy; quantifying size and shape of soil pores, and relating the measurements to research findings and quantifying tropics response of nematode species to electric fields from photographs of nematodes distributed on gels for studies of nematode host-finding behaviour.

(P. Smith)

## Training

Workshops and seminars on various topics took place fortnightly, beginning in the autumn, with all members of the Department participating. Most were well attended and the time spent on training should show benefits through increased computer awareness and the reduction in calls for support.

(R. Kidger)

## Graphics

Faster methods of creating graphs using microcomputers were evaluated jointly with Visual Aids.

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[1]Physiology and Crop Production Department

Quality graphs in colours were produced by a Hewlett Packard Paintjet printer driven from a DCS 286 PC with a colour monitor. Various graphics packages were investigated, and the Harvard Graphics package was selected and purchased.

Use of the plotter continued to increase, with A3 conference poster work being plotted in liquid ink form for the first time. These posters were produced on request to assist the Graphics Officer with a heavy work load. After a collaborative assessment with Visual Aids, an IBM desk top publishing system was purchased and installed in Visual Aids, under the control of the Graphics Officer.

(R. Kidger, I. Black, J. Gorrod)

Databases

Collaborative work continues with Queen's University, Belfast, and DANI to produce a microcomputer package to make available the information in HERBREX using a structured text-retrieval program, MICROHERB. To suit the requirements of the latter, minor changes were made to the lists of ornamental species recommended for use with particular chemicals. In addition, a computer program, HERBCHECK, was written to automate the process of conversion. The Foxbase PC database package was upgraded and used for further development of the raspberry breeding database, in particular, to optimise the selection process of breeding material.

(P. Smith, R. J. Clark)

# VIROLOGY

B. D. HARRISON

Research on the molecular biology of plant viruses increasingly is directed to obtaining a detailed knowledge both of viral genes and of the structure and functions of the proteins they encode. A wide variety of methods are used to achieve these objectives: nucleotide sequencing to delineate and characterise viral genes; expression of the encoded proteins in genetically engineered bacterial, animal or plant systems; and identification of structural features of the viral proteins using monoclonal antibodies and site-directed mutagenesis to alter such features in predetermined ways. A parallel set of approaches are used to study the nature and roles of the regulatory nucleotide sequences that control the functions of the viral genomic nucleic acid itself. This work is revealing a fascinating variety of systems in different groups of plant viruses, and understanding of the processes and interactions involved in genome function is becoming more complete for viral genomes than for any others. Hitherto it has been economical to rely on collaborators elsewhere to apply some of the techniques mentioned and we intend that these collaborations shall continue. However, the increase in such work has, where appropriate, required the development of competence to do it in-house. The value of this growth in expertise can already be seen in this year's report.

Several lines of work exemplify molecular approaches to plant virology and the more practical applications that can result from the knowledge gained. For example, determination of the complete nucleotide sequence of the genomic RNA of potato leafroll luteovirus has led to the transformation of potato plants with a DNA copy of its coat protein gene as an approach to creating genetically engineered virus resistance. In work on cucumber mosaic virus, transgenic plants have been produced that combine satellite-mediated and coat protein-mediated virus resistances. Studies on variation in the particle protein of whitefly-transmitted geminiviruses infecting cassava have resulted in the production of monoclonal antibodies capable of detecting and assaying numerous other geminiviruses that are poorly studied but cause important diseases in other tropical crops.

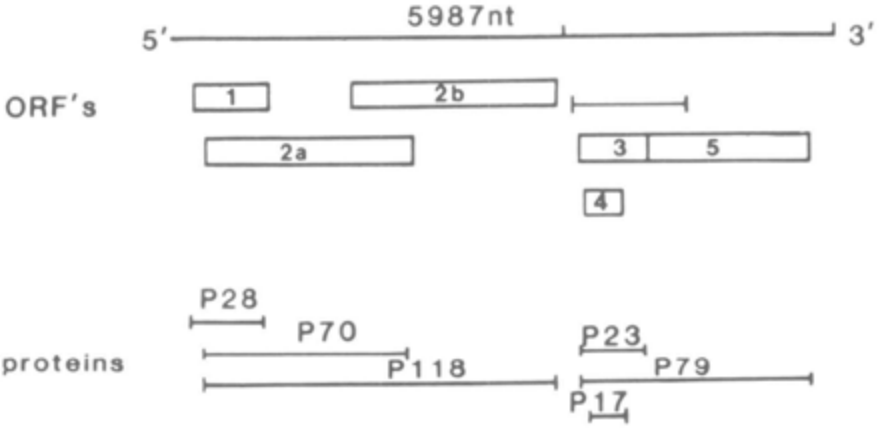
Noteworthy advances in other aspects of virology include the use of antiserum to a potyvirus non-structural protein to detect virus infection in narcissus, determination of the effect of virus infection on intercellular symplastic transport of peptides. demonstration of the roles of different

satellite nucleic acids in causing different forms of groundnut rosette disease, description of ultrastructural abnormalities in strawberry affected by June Yellows, and further indications of differences in nematode vector specificity among strains of tobacco rattle tobravirus. Research was aided by installation of a Phillips CM10 electron microscope, an instrument which is designed to handle biological specimens and is providing excellent results, some of which are illustrated in the pages that follow.

The genome of potato leafroll luteovirus (PLRV) [PU 25(d)]

A sequence of 5987 nucleotides was deduced for PLRV RNA. The sequence comprises two large regions of potential coding sequence, and non-coding regions of 174 nucleotides and 141 nucleotides at the 5′ and 3′ ends respectively. The results suggest, but do not prove, that the terminal sequences are complete. The coding sequences in PLRV RNA are arranged in six open reading frames (Fig. 1). The expression of these

**Figure 1**




**Structure of the RNA (5987 nucleotides) of potato leafroll luteovirus. The horizontal boxes represent the open reading frames (ORFs). The probable translation products (proteins), including the readthrough proteins from ORF 2a/2b and ORF 3/5, are shown below: figures indicate mol. wt (kilodaltons).**

coding sequences seems to be complex. Although ORF 2b is shown overlapping and in a different frame to ORF 2a, circumstantial evidence suggests that ORF 2b is translated when some of the ribosomes that translate ORF 2a change their reading frame to form a longer polypeptide. The amino acid sequence of the translation product of ORF 2b contains a sequence thought to be typical of RNA polymerases and P118 may

therefore be the PLRV-coded polymerase. The putative translation products of ORF 1, 2a and 2b (Fig. 1) correspond in size with those found by *in vitro* translation (mol. wt. 28 K, 70 K, 125 K; *Ann. Rep. 1983,* 186). P118 presumably corresponds to the 125 K *in vitro* product and its appearance is further evidence for frameshift readthrough. This pattern of translation also shows that although some ribosomes initiate the synthesis of P28 others pass further along the RNA to initiate synthesis of P70/118. Similarly the initiation sites for translation of ORF 3 and ORF 4 are close but in different reading frames. P23 was shown to be the coat protein, but is not made during *in vitro* translation of virus particle RNA (*Ann. Rep. 1983,* 186). Circumstantial evidence also suggests that ORF 5 is expressed by readthrough of the ORF 3 termination codon. The resulting polypeptide, P79, would therefore contain the coat protein sequence.

The arrangement of the PLRV genome resembles that of the genomes of beet western yellows (BWYV) and barley yellow dwarf (BYDV) luteoviruses. Comparisons with these luteovirus sequences showed that PLRV proteins resemble those of BWYV and, to a lesser extent, those of BYDV. Least similar were ORF 1 products. BYDV RNA contains no ORF corresponding to PLRV ORF 1, and although the ORF 1 translation products of PLRV and BWYV are both unusually hydrophobic, no sequence similarities were detected between them. The ORF 2 products of PLRV and BWYV are very similar in parts; large segments of the translation products of ORF 2b were 74% identical although there was less similarity between the products of ORF 2a.

The previously reported unexpected similarity between the putative polymerases of PLRV and BWYV on the one hand, and that of the unrelated southern bean mosaic sobemovirus on the other, was in two patches of about 130 amino acids within the translation product of ORF 2b. No similarity was detected between PLRV P118 and the corresponding BYDV protein. In contrast substantial amounts of sequence similarity were found among all three luteoviruses when the products of P3, P4 or P5 were compared. In all comparisons PLRV resembled BWYV more than either resembled BYDV. Most similar were the coat proteins which were 66% (PLRV/BWYV) or 49% (PLRV/BYDV) identical. The coat proteins were most alike in the centre of their sequences and least alike at their N-termini, which were unusually rich in basic amino acids and may therefore be located to the inside of the virus particles.

(M. A. Mayo, D. J. Robinson)

## Detection of non-structural proteins of potato leafroll luteovirus (PLRV) [PU 25(d)]

Additional cloned cDNA copies of parts of the sequence of PLRV RNA were supplied to R. T. Hay, J. W. Lamb and I. Bahner[1], who prepared fusion proteins that contain amino acid sequences from parts of P28, P118

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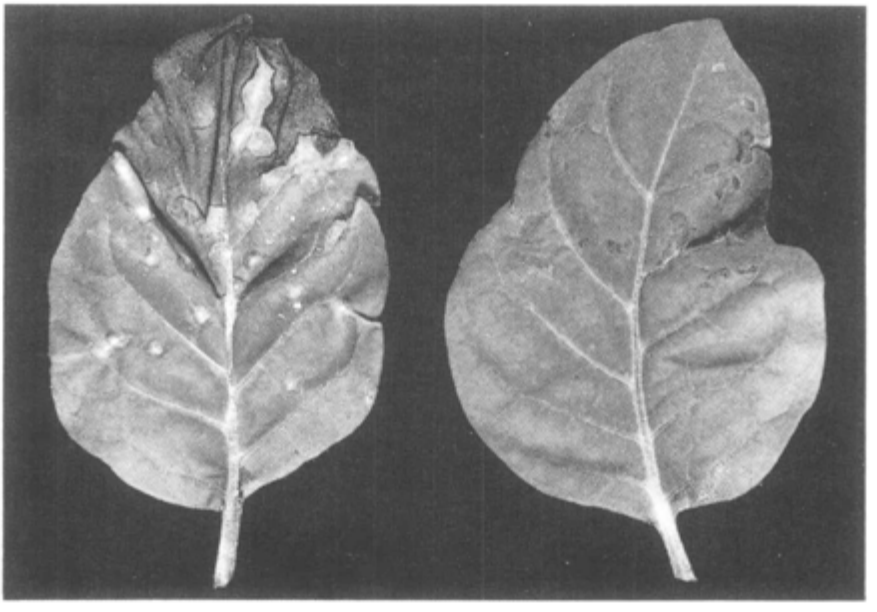
and the ORF 5-coded part of P73. Using the fusion proteins, the production of antisera to each non-structural protein has been started. In initial experiments, antisera to sequences near the centre of P73 were found to react with proteins extracted from PLRV-infected tobacco protoplasts.

(M. A. Mayo)

Biological properties of a tobacco rattle tobravirus (TRV) NM-type isolate derived from a full-length cDNA clone [PU 25(b)]

pTR7116 is an isolate (supplied by W. D. O. Hamilton[1]) obtained by inoculating plants with RNA transcripts from a full-length cDNA clone of RNA-1 of TRV strain SYM. Such an isolate should be equivalent to isolates, known as SYM-NM, made by inoculating plants with SYM RNA-1 itself. Like SYM-NM, pTR7116 does not produce nucleoprotein particles. However, pTR7116 induces more severe symptoms in inoculated plants than does SYM-NM, including large necrotic lesions in inoculated leaves of Samsun NN tobacco (Fig. 2) and lethal systemic necrosis in *Nicotiana clevelandii* and *N. benthamiana*. Moreover, attempts to reconstruct

**Figure 2**



**Symptoms induced in inoculated leaves of Samsun NN tobacco by tobacco rattle tobravirus strains pTR7116, showing large necrotic lesions (left), and SYM-NM, showing scattered necrotic flecks (right).**

[1]AGC, Cambridge

a particle-producing (M-type) isolate by inoculating plants with pTR7116 and RNA-2 from TRV strain PRN were unsuccessful, although M-type isolates were readily obtained from inocula containing SYM-NM and PRN RNA-2. Thus, pTR7116 RNA seems to be defective in its ability to combine with protein to form virus particles, and the same defect may account for the difference in symptoms. Whatever the origin of the defect, which presumably is an expression of a difference between the nucleotide sequences of pTR7116 RNA and SYM RNA-1, its analysis should provide useful information about the molecular bases of symptom production and of particle assembly by TRV.

(D. J. Robinson)

Nucleotide sequencing of raspberry ringspot nepovirus (RRV) RNA [PU 25(b)]

Previous work (*Ann. Rep. 1987*, 178) suggested that cloned cDNA copies of RRV RNA had been isolated that represented about half of the 12 kb genome. In further work several clones proved to be unstable and all the remaining clones tested hybridized strongly with RRV RNA-2. Seven of these were mapped by sequencing and restriction enzyme digestion to a region of about 2 kb at the 3′ end of the molecule. Restriction enzyme mapping suggests that other clones represent at least a further 1 kb of the genome.

(J. Wardell[1], M. A. Mayo, D. J. Robinson)

Polypeptides in protoplasts infected with raspberry ringspot nepovirus (RRV) [PU 25(b)]

The number, sizes and apparent isoelectric points of polypeptides specific to infection by RRV (strain S) were determined by two-dimensional analysis, which combined isoelectric focusing with SDS-polyacrylamide gel electrophoresis of proteins made radioactive by the incubation of infected protoplasts in media containing $^{35}$S-methionine.

The previous estimate of the number of infection-specific polypeptides in *Nicotiana clevelandii* protoplasts was increased to between 25 and 28; several of these could be resolved into species with identical mol. wt. but slightly different isoelectric point, and are therefore thought to be charge isomers. The largest polypeptide had a mol. wt. of 210K (presumably the translation product of the 8 kb RNA-1) but most had mol. wt. of 20 to 60K. Most of these polypeptides were also detected in tobacco protoplasts infected with RRV-S, and in *N. clevelandii* protoplasts infected with the E strain of RRV, whereas most of the polypeptides specific to infection of similar protoplasts with tobacco ringspot nepovirus* differed from the RRV-specific species in mol. wt. or isoelectric point, or both. Thus the infection-specific polypeptides are virus-specific and probably virus-coded.

[1]Short-term Appointment
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Although RRV-S and RRV-E are representatives of different serotypes of RRV, the similar sizes and isoelectric points of the proteins they induce implies that equivalent proteins have similar amino acid sequences or have conserved a balance between acidic and basic residues.

When $^{35}$S-methionine was supplied to protoplasts at different times after infection and polypeptides were analysed 4 to 6 h later, most RRV-specific proteins accumulated during each of the 'pulses'; no evidence was obtained for sequential processing of larger polypeptides into smaller ones. The detection of synthesis of high mol. wt. proteins at relatively late times after infection confirms the earlier conclusion from the results of serological assays that RRV-specific protein synthesis in infected protoplasts continues for at least 3 days after inoculation.

Fractionation of $^{35}$S-methionine-labelled, RRV-infected protoplasts showed that some RRV-specific proteins were associated with particulate fractions containing chloroplasts and cell membranes, whereas others were largely unattached to easily sedimentable structures. However there was no evidence for the accumulation of any particular RRV-specific protein in the incubation medium during culture.

The sum of the mol. wt. of the RRV-specific polypeptides detected greatly exceeds the coding capacity of RRV RNA. Thus many of the polypeptides detected were probably products of proteolytic processing of larger polyproteins made by translation of the RNA species, as occurs in cells infected with, for example, comoviruses and potyviruses. As with these viruses, interpretation of the complex mixture of RRV-specific proteins should be greatly facilitated by knowledge of the nucleotide sequence of RRV RNA.

(O. Acosta[1], M. A. Mayo)

Cloned DNA copies of raspberry bushy dwarf virus (RBDV) RNA-3 [PU 25(b)]

Previous work (*Ann. Rep. 1984*, 182) showed that the smallest RNA species (RNA-3; 1 kb) of RBDV codes for the coat protein of the virus particles. Purified RNA-3 was polyadenylated, and copied with reverse transcriptase, DNA polymerase and RNase H to form cDNA, which was cloned in the plasmid vector pUC19. Clones containing substantial amounts of sequence specific for RNA-3 were selected. The sizes of DNA fragments released from these clones by restriction endonuclease digestion suggest that they contain >80% of the RNA-3 sequence.

(M. A. Mayo, A. F. Murant, J. H. Raschké)

Genetic engineering of virus resistance [PU 25(c)]

Previous work showed that transformation of tobacco plants with DNA copies of a benign satellite RNA of cucumber mosaic cucumovirus (CMV) makes them resistant to the effects of satellite-free isolates of CMV. The

[1]Research Student

transgenic plants retain a normal susceptibility to infection but relatively little CMV accumulates in them, symptoms remain very mild and the plants are poor virus sources for vector aphids. In further work, three additional satellite-free CMV isolates, including one from Fiji, were found to produce negligible disease symptoms in the satellite-transformed plants. When transformed plants were inoculated with CMV together with the unrelated potato Y potyvirus (PVY), the symptoms induced were less severe than in non-transformed plants but slightly more severe than in transformed plants inoculated with PVY alone. Tests were also made to ascertain whether variant forms of CMV or satellite RNA that induce symptoms of increased severity are selected when satellite-free CMV infects satellite-transformed tobacco. Isolates passaged three times through satellite-transformed plants did not develop an ability to overcome the tolerance of such plants to infection. Thus several lines of evidence encourage the view that the satellite-induced tolerance expressed by the transformed plants will be durable and effective against a range of CMV strains.

In experiments in collaboration with M. Jaegle[1] and D. C. Baulcombe[2], aimed at creating an aphid non-transmissable satellite RNA to use for transforming plants, tests were made on a hybrid satellite RNA produced at Cambridge. This satellite, which consisted of the 5′ and 3′ terminal regions of the I17N satellite and the central 142 nucleotides of the Y satellite, was readily transmitted by aphids together with CMV but when introduced into a culture of tomato aspermy virus it was transmitted to only about a quarter of the plants infected by aphids carrying virus from such sources.

When tobacco plants with a second kind of transgenic resistance, which was conferred by transformation with the CMV particle protein gene, were inoculated manually with highly infective CMV, the following sequence of events occurred. In the inoculated leaves, CMV became established at fewer sites, and so replicated to a smaller extent, than in control leaves. Perhaps as a result, infection was slower to establish in systemically infected tip leaves, but once the virus was established there it reached as great a concentration as in control plants. This type of resistance was therefore mainly expressed as resistance to infection whereas satellite-mediated resistance is essentially a tolerance of infection. By making hybrids between plants with each kind of transgenic resistance, progeny were produced that express both kinds. These plants were resistant to infection, the systemic spread of infection in them was erratic, and in systemically infected leaves CMV concentration was low and symptoms were barely visible. This combination of resistances therefore seems more effective than either of its components separately.

[1]IPSR (Cambridge Laboratory)
[2]Sainsbury Laboratory, Norwich

In collaboration with W. D. O. Hamilton[1], tobacco plants transformed so as to produce various kinds of antisense RNA of tobacco rattle tobravirus were tested for susceptibility to infection with the RNA-1 of the homologous virus, and with the unrelated tobacco necrosis virus. When opposite half-leaves were inoculated with each virus and the ratio between the numbers of lesions produced by the two viruses calculated, the 'antisense plants' were found to be, at the most, only slightly more resistant to TRV than the control plants.

(B. D. Harrison, E. A. Murant[2])

Work was started to test the idea that resistance to potato leafroll luteovirus (PLRV) can be conferred on potato plants by transforming them with the particle protein gene of this virus. This approach has not previously been tried with a virus that is confined to phloem tissue. A cDNA clone which appeared to contain the complete open reading frame coding for PLRV coat protein was subcloned into a vector designed for high level transient expression in mammalian cells (pTR315, supplied by Beecham Pharmaceuticals) to give plasmid pSCR105. Extracts of HeLa cells transfected with pSCR105 were shown to contain PLRV coat protein by immunoblotting. The PLRV cDNA was then subcloned into pROK2 (supplied by M. Bevan[3]) to give pSCR107. This new plasmid was used in the *Agrobacterium* binary Ti plasmid system in attempts to transform cells in potato leaf and tuber discs. Several putative transgenic plants were isolated using kanamycin resistance encoded on pSCR107 and were regenerated to produce normal-looking plants.

(B. Reavy, A. Kumar[4], M. A. Mayo)

Effects of viral infection on intercellular symplastic movement [PU 25(f)]

Although the infectious component of most plant viruses can move from cell to cell via plasmodesmata, little is known about the mechanism of this movement. One possibility is that virus infection alters plasmodesmatal function in such a way as to allow the passage of viral material. Work was therefore begun to study the effects of viral infection on the intercellular movement of compounds introduced into intact tissue by microinjection, assisted by a microinjection system developed for use in conjunction with an epifluorescence microscope.

Fluorescent markers were synthesised by coupling fluorescein isothiocyanate (FITC) to a range of peptides which, in addition to carboxyfluorescein and Lucifer Yellow CH, formed a set of membrane-impermeable fluorochromes with mol. wt. ranging from 376 to 839. These markers were injected into the cytoplasm of epidermal cells overlying secondary leaf veins in virus-

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[2]Short-term Appointment
[3]IPSR (Cambridge Laboratory)
[4]Tissue Culture Department

free *Nicotiana clevelandii* and their rate of symplastic movement into neighbouring cells observed. By this method the molecular size limit for plasmodesmatal conductance was determined as approximately 680 to 840 daltons, with movement depending on steric as well as mol. wt characteristics. Tests made on *N. clevelandii* leaves systemically infected with tobacco rattle tobravirus, potato Y potyvirus or tomato black ring nepovirus indicated that infection did not alter movement of the fluorescent probes. In carrot mottle virus-infected *N. clevelandii*, however, plasmodesmatal conductance was diminished. Only 27% of injections of FITC-glutamate (mol. wt. 536) resulted in movement of dye from the injected cell compared with 100% for virus-free plants. This may be because the cell wall outgrowths associated with plasmodesmata in carrot mottle virus-infected *N. clevelandii* (Murant *et al., Journal of General Virology* **21** 269, 1973) interfere with intercellular transport.

(P. M. Derrick[1], H. Barker, K. J. Oparka[2])

Restriction of potato leafroll luteovirus (PLRV) multiplication in potato genotypes [PU 13(j)]

Previous work (*Ann. Rep. 1983,* 194) identified a hitherto unrecognised type of resistance to PLRV that is expressed as a severe restriction on the amount of virus which accumulates in infected potato plants. Such plants are a poor source of PLRV for vector aphids to transmit to other plants. This type of resistance occurred mostly in potato cultivars and genotypes known from field exposure trials to be resistant to infection with PLRV, suggesting that the two kinds of resistance are linked. Further work was begun (1) to devise a sampling procedure which gives reliable and reproducible estimates of PLRV concentration, and (2) to test, in a wider range of genotypes, the extent of the association between resistance to infection and decrease in PLRV accumulation in leaf tissue.

A microcomputer-aided ELISA technique was devised which can make accurate quantitative measurements of PLRV concentration in up to 100 leaf samples per day. Results from samples stored for several weeks at −18°C were inconsistent and differed appreciably from those for fresh samples, which were therefore used in all further tests. The concentration of PLRV antigen was measured in the leaves of glasshouse-grown plants of about 50 SCRI-bred potato genotypes with secondary infection. Repeated tests on different dates gave relatively consistent estimates of virus concentration, the virus content of lower leaves being similar to, but usually greater than, that of upper leaves. The main ratio (lower/upper) for all genotypes was 2.0 (range 0.5-5.4). There were large consistent differences between genotypes in PLRV concentration in leaf tissue (50-1500 ng/g) indicating that the differences have a heritable component. Several additional

[1]Short-term Appointment
[2]Physiology and Crop Production Department

genotypes in which PLRV accumulation is limited to about 50 ng/g leaf were identified. However, despite the indications from previous work, the new, more extensive tests provided little evidence for an association between virus concentration and resistance to infection with PLRV. Thus, it is unlikely that measurements of PLRV concentration in infected tissue can provide the sole basis of a screen for resistance. Nevertheless, the above technique will enable genotypes with one type of resistance to be selected and will facilitate research to determine the genetic control of restriction of PLRV accumulation in leaves.

(H. Barker)

Viruses dependent on luteoviruses for transmission by aphids [PU 25(a)]

A number of viruses are known that depend on definitive or tentative luteoviruses for transmission by aphids, probably through the packaging of their genomic RNA molecules in the coat protein of the helper virus. Four such viruses, bean yellow vein banding (BYVBV), carrot mottle (CMotV), groundnut rosette (GRV)* and tobacco mottle*, and two others with similar properties from carrot and parsley, induce dsRNA species of c. 4.6 (dsRNA-1) and 1.3 (dsRNA-2) kbp in infected leaves. Some induce additional dsRNA species. Thus GRV has a 900 bp dsRNA (dsRNA-3). Probing with cDNA revealed sequence homology between dsRNA-1 and dsRNA-2 of CMotV, and between dsRNA-1 and dsRNA-2 of GRV but not between the corresponding dsRNA species of different viruses. No reaction was observed between cDNA to GRV dsRNA-3 and any other dsRNA species of any of the viruses except perhaps some of the minor ones of BYVBV. The similarities in general properties among these viruses suggest that they should be placed in a new plant virus taxonomic group, for which we propose the name 'umbravirus' (Latin *umbra*, a shadow, an uninvited guest that comes with an invited one).

(A. F. Murant, D. J. Robinson, J. H. Raschké, R. Rajeshwari[1])

In previous studies (*Ann. Rep.*1980,* 101) aphid transmission of CMotV was shown to be assisted not only by its usual helper, carrot red leaf luteovirus, but also by potato leafroll and beet western yellows luteoviruses. However, no evidence was obtained for packaging of CMotV RNA in coat proteins of pea enation mosaic virus, or of strawberry latent ringspot or tomato black ring nepoviruses. In further work, mixed infections were established in *Nicotiana clevelandii* or *N. benthamiana* of CMotV, GRV or groundnut streak necrosis virus (GSNV)* with solanum nodiflorum mottle sobemovirus (SNMV)*. Preparations made from these doubly infected plants by treatment of leaf extracts with chloroform or butan-1-ol, followed by differential and sucrose density gradient centrifugation, contained only SNMV-like particles but possessed the infectivity of both the viruses in the

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[1]Short-term Appointment

original mixture, even though treatment with organic solvents normally abolishes the infectivity of CMotV, GRV or GSNV in extracts of singly infected plants. Furthermore, the GRV infectivity in virus particle preparations made from plants mixedly infected with GRV and SNMV was abolished by treatment with antiserum to SNMV. These results suggest that the RNA molecules of GRV, and probably of CMotV and GSNV, can be packaged in coat protein of SNMV, which leads to the prediction that these viruses are transmissible from mixed infections with SNMV by the vectors of SNMV (coccinellid beetles). The satellite RNA of GRV (see below) also seems able to be packaged in SNMV particles but no evidence was obtained that it can replicate except in the presence of GRV.

(A. F. Murant, J. H. Raschké)

Viruses associated with groundnut rosette disease [PU 12(b)]

Groundnut plants showing symptoms of rosette disease contain groundnut rosette 'umbravirus' (GRV)*. GRV depends for transmission by aphids on groundnut rosette assistor luteovirus (GRAV)*, which itself causes no symptoms in groundnut. No virus-like particles have been reported for GRV but infected plants contain infective ssRNA. Double-stranded RNA extracted from infected plants contains two species related to the virus genome as well as an abundant species of 0.9 kbp (dsRNA-3), which was shown (*Ann. Rep. 1987*, 193) to be the replicative form of a satellite RNA which is largely responsible for the symptoms of rosette disease. In further studies, satellite-free cultures of GRV were prepared from isolates obtained from chlorotic and green forms of rosette from Nigeria, and from chlorotic and mosaic forms of rosette from Malawi. All gave symptomless infection or only transient chlorosis in groundnut. When satellite RNA from isolates of Nigerian green or Malawian chlorotic rosette was re-introduced into these cultures in homologous or heterologous combinations, the reconstituted isolates induced symptoms in groundnut similar to those given by the cultures from which the satellite was derived. Thus it appears that the different forms of rosette disease are largely determined by different variants of the satellite. In addition to the variants of the satellite associated with the different forms of rosette, others have been found that induce no symptoms in groundnut.

GRV cultures from Malawi occasionally yield isolates that induce a brilliant yellow blotch mosaic (YBM) symptom in *Nicotiana benthamiana*. This symptom is determined by a further variant of the satellite RNA. The YBM variant induced YBM symptoms in *N. benthamiana* not only in association with its homologous GRV isolate but also in association with each of the satellite-free GRV cultures mentioned above (Fig. 3). However, GRV isolates containing YBM satellite gave only mild rosette symptoms in groundnut. The YBM satellite was used as a convenient

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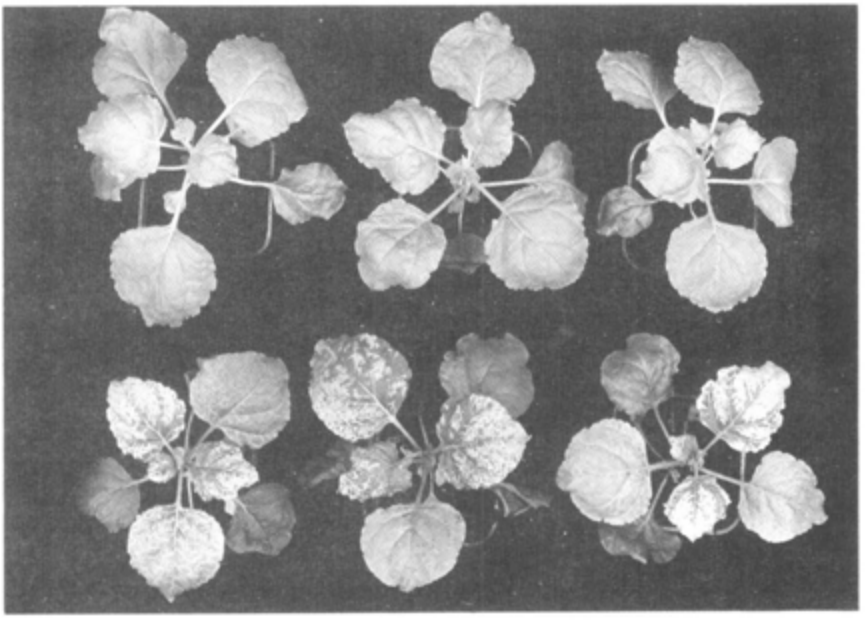
Figure 3



**Symptoms in *Nicotiana benthamiana* plants each infected with a different satellite-free isolate of groundnut rosette virus (upper row), and infected with cultures of the same isolates to which YBM satellite RNA was added (lower row).**

marker in experiments to find out more about the interactions between GRV and its satellite. *N. benthamiana* plants inoculated first with satellite-free isolates of GRV and then with the YBM satellite rapidly developed YBM symptoms; in contrast, when the first inoculation was done with isolates of GRV containing the normal form of the satellite the plants did not show YBM symptoms, except for the appearance of sporadic yellow flecks on upper uninoculated leaves. This suggests that there is competition between different forms of the satellite for infection and/or symptom expression in plants. YBM symptoms developed when satellite-free cultures of GRV were inoculated to leaves that had been rubbed with heat-denatured dsRNA of the YBM satellite up to 11 days previously, showing that the denatured satellite has considerable stability *in vivo*. Although the genome-related dsRNA of GRV is not infective unless the RNA strands are separated by heat-denaturation, the satellite dsRNA does not need to be denatured to be infective. Presumably denaturation of the GRV genome-related dsRNA is necessary for expression of the viral replicase which can then transcribe the satellite dsRNA, whether denatured or not. The YBM satellite did not multiply in the presence of carrot mottle virus, groundnut streak necrosis virus* or tobacco mottle virus.*

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The GRV satellite dsRNA was purified by electrophoresis in low gelling temperature agarose of extracts made from infected leaf tissue. Electrophoresis in 1% agarose after denaturation with formaldehyde/formamide at 80-90°C or with glyoxal revealed a single band of estimated mol. wt. $0.3 \times 10^6$, as expected for a ssRNA of c. 900 bases. Examination of denatured nucleic acid in the electron microscope by the Kleinschmidt technique revealed only linear molecules.

A start was made on the preparation of complementary DNA clones, using as template the unfractionated dsRNA from a satellite-containing culture of a chlorotic form of GRV from Nigeria. The dsRNA molecules were polyadenylated, then denatured and copied to cDNA using reverse transcriptase. Second strand cDNA was synthesized by using *E. coli* DNA polymerase I and RNase H. The majority of transcripts obtained were around 800 bp and the maximum size was about 4000 bp.

(I. K. Kumar[1], A. F. Murant, D. J. Robinson, G. H. Duncan)

Isolates of tobacco rattle tobravirus (TRV) transmitted by naturally viruliferous nematodes [PU 24(e)]

Continuing studies of the TRV isolates transmitted by different populations of naturally viruliferous trichodorid nematodes (see Report p. 118) have revealed further examples of the remarkable variation in this virus and of the association of different variants with each vector species. Most frequently encountered were isolates closely related serologically to strain PRN; isolates of this serotype were transmitted by *Paratrichodorus pachydermus* from Barry, Tayside, from Morton and Kinshaldy, Fife, from Wageningen, The Netherlands* and from Sweden*. Three isolates* from potato from Denmark (supplied by B. Engsbro[2]) were also of this serotype. In contrast, four isolates transmitted by individual *Trichodorus primitivus* from Oxford were serologically related to strain RQ. All 13 M-type isolates* transmitted by *P. teres* from a site in the Netherlands were serologically similar to the Oregon strains of TRV. Variation among the 13 isolates was evident from the symptoms they induced in *Nicotiana glutinosa,* which ranged from barely discernible or scattered necrotic ringspots to severe systemic necrosis. Isolates transmitted by *P. anemones* from a site at South Carolina, Yorkshire were similar to strain SYM in invading *Chenopodium quinoa* systemically, but they did not become systemic in *C. amaranticolor* or react with antisera to strain SYM or to any other TRV strain tested. However, when one of these isolates was tested with a cDNA probe for TRV RNA-1, it reacted, suggesting that it represents yet another serotype of TRV.

(D. J. Robinson, A. T. Ploeg[3], D. J. F. Brown[4])

[1]Short-term Appointment
[2]Institute of Plant Pathology, Lyngby, Denmark
[3]Research Student
[4]Zoology Department
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Relationships detected among potato leafroll and other luteoviruses with monoclonal antibodies [PU 25(g)]

Twenty-seven monoclonal antibodies (MAbs) produced to the particles of four luteoviruses [barley yellow dwarf (BYDV), potato leafroll (PLRV), beet western yellows (BWYV) and soybean dwarf (SDV)], were tested for reactivity against 17 strains of seven luteoviruses by triple antibody sandwich ELISA. The MAbs used were: three anti-BYDV-MAV (MAV), three anti-BYDV-PAV (PAV), five anti-BYDV-RPV (RPV), six anti-BWYV, six anti-PLRV and four anti-SDV. The antigens comprised of luteovirus isolates from Britain, USA, Canada and Nigeria, and the tests were done at Agriculture Canada Research Station, Vancouver and at SCRI.

Virus-specific MAbs were identified for each virus to which MAbs were produced, whereas other MAbs reacted with a range of heterologous viruses. Common epitopes were identified on the particle proteins of MAV+PAV, PAV+PLRV, PAV+PLRV+BWYV–BMY, RPV+BLRV, RPV+PLRV, RPV+BLRV+BWYV, BWYV+PLRV, BWYV+SDV, PLRV+GRAV and PLRV+SDV, (other luteovirus abbreviations: BLRV = bean leafroll, BWYV–BMY = beet mild yellowing, GRAV = groundnut rosette assistor, CRLV = carrot red leaf and SMYEV = strawberry mild yellow edge). The minimum number of epitopes identified on each virus varied from one to five. None of the antibodies detected BYDV-RMV, CRLV or SMYEV.

(C. J. D'Arcy[1], L. Torrance and R. R. Martin[1])

Monoclonal antibodies to potato V potyvirus (PVV) [PU 13(k)]

In further tests with monoclonal antibodies (MAbs) to PVV, four potyviruses from the Ivory Coast reacted with MAb SCR 39 (strongly) and/or SCR 40 (weakly) but none reacted with the six other MAbs tested. Closer relationships were found with two potyviruses from South America. MAbs SCR 38, 39, 40 and 43 all reacted strongly with wild potato mosaic virus from Peru, and 4 to 7 of the eight MAbs reacted with different isolates of Peru tomato virus (PTV), tested in collaboration with E. N. Fernandez-Northcote[2]. Moreover PTV was the only other virus to share with PVV more than one of the four conformation-sensitive epitopes that were detectable. In contrast, neither of two fungus-transmissible viruses with filamentous particles from Japan, barley yellow mosaic and wheat yellow mosaic, reacted with any of the MAbs. This supports other evidence that these two fungus-transmitted viruses are less closely related to potyviruses *sensu stricto* than was previously supposed.

The epitopes that react with MAbs SCR 38, 39, 40 and 43 appear to be internal in the virus particle but react in immunoblots (*Ann. Rep. 1987*,

[1]Agriculture Canada Research Station, Vancouver.
[2]CIP, Peru

188). Mild treatment of purified PVV particles with trypsin converted the particle protein from mol. wt. 33K to 29K, presumably by removing sequences at the 5′ and 3′ ends, and smaller amounts of material of 27, 25 and 17K. All four products reacted with SCR 40, the 29K and 27K material reacted with SCR 38 and 43, but only the 29K product reacted with SCR 39. Treatment of PVV particle protein with cyanogen bromide yielded another set of products. Those reacting with SCR 40 were very similar to the products reacting with polyclonal antibody, suggesting that SCR 40 is specific for the immunodominant region of the protein. The other three MAbs reacted with similar sets of products which, however, differed from those detected by SCR 40. Comparison of the known amino acid sequences of the particle proteins of three strains of potato Y potyvirus from Britain, France and The Netherlands and of the reactions of these strains with SCR 38, 39 and 43, together with the results of the protein degradation experiments, suggest that the epitope detected by SCR 39 is nearest the C terminus, with those detected by SCR 38 and 43 both being a little more towards the N terminus and possibly overlapping with one another. The epitope detected by SCR 40 may be much nearer to the N terminus.

Immunogold labelling was used to locate epitopes on PVV particles. Purified virus particles were attached to electron microscope grids which were pretreated with poly-L-lysine, then incubated on drops containing different MAbs. The MAbs were then detected by exposure to gold-labelled antibody to mouse globulin. MAbs SCR 36, 37, 41 (weakly) and 42 all reacted with sites along the length of the virus particle, as expected (Fig. 4). The other MAbs reacted weakly (SCR 38, 43) or not at all (SCR 39, 40). These reactions were not affected by pretreating the particles with trypsin, which suggests that none of the epitopes includes the N-terminal portion or the extreme C-terminal portion of the protein, and that none was revealed by cleaving the N- and C-terminal sequences from the trypsin-resistant core region. The apparent occurrence of virus-specific epitopes in the core region was not observed in work done elsewhere with other potyviruses.

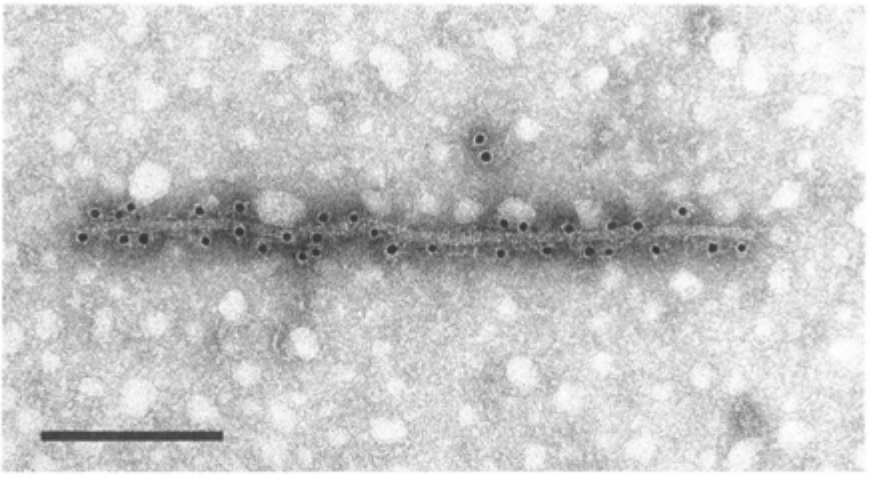
(M-J. Farmer[1], E. W. Milne, I. M. Roberts, B. D. Harrison)

Properties of monoclonal antibodies to the coat protein of tomato black ring nepovirus (TBRV) [PU 25(g)]

Seven hybridoma cell lines that secrete monoclonal antibodies (MAbs SCR 45 to 51) specific to particles of TBRV strain A (Scottish serotype) were produced. Table 1 shows their immunoglobulin sub-types, ability to react in immunoblotting tests and reactivity in triple antibody-sandwich ELISA with isolates from the two serotypes of TBRV* and with cocoa necrosis*, a serologically related nepovirus. The epitopes that react with SCR 45 to 49 are distinguishable and those detected by SCR 47 and 49 seem to react with

[1]Short-term Appointment
*Held under DAFS licence

Figure 4



**Electron micrograph of a particle of potato virus V coated with monoclonal antibody SCR 36. The antibody was detected with anti-mouse globulin coupled to gold particles of 10 nm diameter (black spots). Bar represents 200 nm.**

**Table 1. Properties of monoclonal antibodies to tomato black ring nepovirus (Scottish serotype) (TBRV-S)**

| Monoclonal antibody | Globulin sub type | Reaction in immunoblots | Reaction in ELISA with TBRV-S | TBRV-G* | CNV* |
|---|---|---|---|---|---|
| SCR 45 | IgM | 0 | ++ | (+) | 0 |
| SCR 46 | IgG2a | 0 | ++ | ++ | 0 |
| SCR 47 | IgG1 | + | ++ | (+) | 0 |
| SCR 48 | IgG1 | 0 | ++ | 0 | 0 |
| SCR 49 | IgG1 | + | ++ | 0 | 0 |
| SCR 50 | IgG2a | 0 | ++ | ++ | 0 |
| SCR 51 | IgG1 | + | ++ | 0 | 0 |

linear sequences of amino acids that are not disrupted by denaturation. SCR 46 and 50 detect both TBRV serotypes which, in double diffusion assays using rabbit polyclonal antisera, differ by an SDI of about 3. In contrast, the other MAbs are specific for the Scottish serotype, or react only weakly with the German one. None of the MAbs reacted with cocoa necrosis nepovirus.

SCR 47, 49 and 51 were used in immunoblotting experiments in which TBRV coat protein was partially cleaved before electrophoresis. No

*TBRV-G = tomato black ring nepovirus, German serotype; CNV = cocoa necrosis nepovirus.

differences were detected between any of the MAbs. Cleavage by n-chlorosuccinimide generated about 14 products with mol. wt. between 52 and 10 K and the smallest that reacted with the MAbs had a mol. wt. of about 13 K. Cleavage with cyanogen bromide generated about 10 products, of which two with mol. wt. of about 15 and 12 K were the most prominent. The MAbs reacted most strongly with species with approximate mol. wt. of 32, 26, 19, 14, and 11 K, suggesting that they were made by successive removals of serologically non-reactive parts of the protein molecule away from the 11 K mol. wt. polypeptide which contains at least two epitopes, one represented in a modified form in protein of the German serotype and one specific to the Scottish serotype particles.

(M-J. Farmer[1], M. A. Mayo)

Monoclonal antibodies to Indian cassava mosaic geminivirus (ICMV) [PU 12(a)]

To study the variation between strains, and relationships, of ICMV, a panel of 17 mouse monoclonal antibodies (MAbs) was prepared to the virus particles. Tests by indirect ELISA against a wide range of geminiviruses showed that the MAbs detected at least eight distinct and two partially distinct epitopes. All 16 ICMV isolates* tested, including examples from Karnataka, Kerala and Tamil Nadu States, reacted with every MAb, indicating that these isolates are closely serologically related. In contrast, only two MAbs reacted with Group B (East African) isolates of African cassava mosaic virus (ACMV), and these reactions were weak. However, the MAbs detected up to five different epitopes in Group A isolates of ACMV from West Africa and allowed some isolates to be distinguished that were not differentiated with the MAbs prepared previously to a Group A isolate. Thus the different Groups of isolates can be distinguished with MAbs to ICMV and, despite the relative geographical distances between their source countries, ICMV isolates are more closely related antigenically to West African than to East African isolates of ACMV.

The MAbs to ICMV could also be used to distinguish other geminiviruses. For example, an uncharacterised virus infecting *Jatropha curcas** from Kerala had six of the eight distinct epitopes of ICMV whereas an isolate infecting *J. glandulifera** had only three. Similarly, whereas euphorbia mosaic geminivirus* from N. America and tomato golden mosaic geminivirus* from S. America have largely similar patterns of reaction with MAbs to a Group A isolate of ACMV, they reacted very differently with the MAbs to ICMV.

(M. M. Aiton[1], B. D. Harrison)

Cloning and nucleotide sequencing of Indian cassava mosaic geminivirus (ICMV) DNA [PU 25(b)]

Serological and nucleic acid hybridization tests both show that virus isolates from mosaic-diseased cassava from India are sufficiently distinct

[1]Short-term Appointment
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from African cassava mosaic geminivirus (ACMV) that they are best considered to be isolates of a distinct geminivirus, ICMV. The nucleotide sequence of the genome DNA of ACMV is already known, and in order to understand more fully the differences between these viruses, a start was made on determining that of ICMV*. Single-stranded DNA from ICMV particles was made double-stranded by using reverse transcriptase and random oligodeoxynucleotide primers, digested with restriction endonuclease EcoRI, and the fragments separated by polyacrylamide gel electrophoresis. Several of the fragments were cloned in the plasmid pUC19, and two of them were sequenced. One of these fragments has a nucleotide sequence closely similar to that of a segment of DNA-1 of ACMV, and therefore presumably represents the corresponding segment of DNA-1 of ICMV. The sequence of the other fragment has no recognizable homology with any part of the ACMV genome, and seems not to be part of a protein coding region. Used as a probe in nucleic acid hybridization tests, the second fragment reacts specifically with isolates of ICMV, but not with isolates of ACMV* or of several other geminiviruses from India. It could therefore be used to identify ICMV isolates.

(D. J. Robinson, X. F. Wang[1])

Variation among East African isolates of African cassava mosaic geminivirus (ACMV) [PU 12(a)]

Work continued on the typing of ACMV isolates from East Africa. In tests on cultures of ACMV from eight clones of cassava from different parts of Malagasy*, and one of *Manihot glaziovii** (supplied by G. M. Lallmahomed[2]) all were within the range of variation of Group B isolates in their reactions with MAbs to an ACMV Group A isolate. However, there was considerable antigenic variation between individual isolates. A similar pattern of variation was found among 12 isolates in cassava from Malawi* (supplied by G. S. N. Phiri[3]). Among Group B isolates, five epitopes were found consistently but three of the epitopes found in Group A isolates were always missing. The other 10 epitopes occurred in some Group B isolates though not in others. This variation is not related to geographical origin within East Africa or to cassava variety, and is greater in extent than that found among Group A or ICMV isolates.

(M. M. Aiton[4], P. M. McGrath[4], B. D. Harrison)

Ultrastructural studies on cassava geminiviruses [PU 25(h)]

In continued work on locating the particle antigen of African cassava mosaic geminivirus (ACMV)* in thin sections of infected leaf tissue by

[1]Visiting Workers
[2]FAO, Antananarivo, Malagasy
[3]Ministry of Agriculture, Thondwe, Malawi
[4]Short-term Appointment
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immunogold labelling (*Ann. Rep. 1986,* 180), mouse monoclonal antibodies (MAbs) prepared to ACMV particles were tested as antigen-specific probes. MAb SCR 18 gave strong specific labelling of nuclear virus inclusions when it was detected with a goat anti-mouse/gold probe, whereas MAb SCR 20 did not. Because SCR 18 detects a sequence-specific epitope whereas that detected by SCR 20 is conformation-sensitive, the failure of SCR 20 to label sections may signify that changes have occurred in the conformation of protein in the virus particle, perhaps because of shrinkage during the embedding process.

Tests were also made to compare the ultrastructural effects of Indian cassava mosaic geminivirus (ICMV)* with those found previously for ACMV (*Ann. Rep. 1986,* 180). The distribution of virus particle antigen, assessed by immunogold labelling, was essentially similar to that of ACMV (*Ann. Rep. 1986,* 180). It was confined to the nuclei of some vascular cells, and of a few cells in the leaf blade. Other ultrastructural features, however, differed from those in ACMV-infected tissue. The large densely stained ring-like structures in infected nuclei were rarely found and no tubular aggregates of virus particles were seen. Some ICMV-infected cells did however contain inclusion bodies, which were of two distinct types: one consisting of masses of unorientated 20 nm-diameter tubules, and the other composed of amorphous protein which, in osmium-fixed tissue, sometimes appeared as short electron-dense stacks of material. ICMV particle antigen was not detected in either type of inclusion body.

(I. M. Roberts, B. D. Harrison)

## Antigenic constitution of whitefly-transmitted geminiviruses from India [PU 12(a)]

In collaboration with V. Muniyappa[1] and A. Varma[2], 10 whitefly-transmitted viruses known or suspected to belong to the geminivirus group were tested during a visit to India, using a panel of 10 monoclonal antibodies (MAbs) to African cassava mosaic geminivirus (ACMV) and 8 MAbs to Indian cassava mosaic geminivirus (ICMV). The following viruses reacted with some of the MAbs: acalypha yellow mosaic, bhendi yellow vein mosaic, bitter gourd yellow mosaic, cowpea golden mosaic, croton yellow vein mosaic, dolichos yellow mosaic, horsegram yellow mosaic, malvastrum yellow vein mosaic, papaya leaf curl and tobacco leaf curl viruses. Cowpea golden mosaic virus reacted with four MAbs to ACMV and only one to ICMV, but the other viruses reacted with at least as many ICMV MAbs as ACMV MAbs. Nearly all the viruses could be distinguished from each other by their pattern of reactions with different MAbs, but there was also some evidence of variation between isolates of the same virus.

[1]University of Agricultural Sciences, Bangalore
[2]Indian Agricultural Research Institute, Delhi
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These results show that all whitefly-transmitted geminiviruses tested to date can be detected with the aid of one or other of the MAbs to ACMV and ICMV. The availability of these antibodies should therefore greatly aid the detection and quantitative assay of a large number of viruses which cause important diseases in tropical crops but are still uncharacterised or only partially characterised.

(M. M. Aiton[1], B. D. Harrison)

Strain variation in tobacco leaf curl geminivirus (Tob LCV) in India [PU 12(a)]

In collaboration with V. Muniyappa[2], MAbs were used to compare isolates of Tob LCV. The objectives were to examine variation among virus isolates from tobacco in different parts of India, to compare isolates from tobacco with those from tomato and to compare isolates from naturally infected weeds with those from nearby tobacco or tomato crops.

More than 70 virus isolates were tested using at least eight MAbs selected in preliminary tests by their ability to detect and distinguish between isolates from tobacco. The results showed that considerable antigenic variation exists among virus isolates from tobacco although three MAbs reacted with all. Isolates from the same field tended to react similarly but those from different States were not more different than those from different localities within a State. Isolates from tomato were more uniform antigenically, and fell within the range of variation of isolates from tobacco. Isolates from weeds near infected tomato crops mostly resembled those from tomato whereas isolates from weeds near infected tobacco crops were more variable and some did not resemble closely those from the adjacent tobacco. Common weed hosts of the virus include *Acanthospermum hispidum, Ageratum conyzoides, Euphorbia geniculata* and *Parthenium* sp.

These results suggest that weed hosts may constitute an important reservoir of Tob LCV and can maintain a wide range of virus strains.

(M. M. Aiton[1], B. D. Harrison)

Properties of okra leaf curl virus (OLCV) [PU 12(c)]

OLCV is a sap non-transmissible geminivirus which occurs commonly in okra (*Abelmoschus esculentus*) plantings in the Ivory Coast. An Ivorian isolate was detected in okra by ELISA with polyclonal and monoclonal antibodies to geminiviruses from cassava. It could be assayed quantitatively in leaf extracts with these antibodies but attempts to purify OLCV particles were hindered by mucilaginous material in the leaves. OLCV shared several epitopes with African cassava mosaic virus (Group A isolate) but only a few with Indian cassava mosaic virus.

(K. P. N'Guessan[3], P. M. McGrath[1], M. M. Aiton[1], B. D. Harrison)

[1]Short-term Appointment
[2]University of Agricultural Sciences, Bangalore
[3]Visiting Worker

Culture of vector whiteflies (Bemisia tabaci) [PU 12(a)]

A culture of *B. tabaci* was established from insects received from the Ivory Coast. Insects reared on okra showed little tendency to breed on cassava or tobacco although they colonised okra freely. They transmitted okra leaf curl virus readily from okra to okra, and occasionally from okra to hollyhock. Low concentrations of the virus could be detected serologically in groups of virus-carrying insects.

(P. M. McGrath[1], K. P. N'Guessan[2], B. D. Harrison)

Cassava Ivorian bacilliform virus [PU 12(a)]

A virus isolated from cassava* from the north-west of the Ivory Coast (*Ann. Rep. 1987*, 191) was transmitted by inoculation with sap to species in the Leguminosae, Compositae, Chenopodiacae, Amaranthaceae, Solanaceae and Aizoaceae, most being symptomlessly infected. Virus particles were purified from systemically infected *Chenopodium quinoa* leaves, which develop obvious symptoms, but yields were only about 0.5-1 mg/kg of leaf material. In the purified preparations, three main components and a possible fourth were resolved by sucrose density-gradient centrifugation. The virus particles are bacilliform, about 18 nm wide and with lengths ranging from 30 to 110 nm. In particle-length distributions, the predominant lengths were 42, 48 and 75 nm, with a possible fourth component of c. 80 nm. Purified particles have an $A_{260}/A_{280}$ value of 1.7 ± 0.05, contain a protein of mol. wt. 22 K and do not react with antisera to other viruses with bacilliform particles of similar sizes (*Ann. Rep. 1987*, 191), including olive latent virus 2. The virus was not transmitted by the aphid, *Myzus persicae*. It seems to be previously undescribed and we propose it shall be named cassava Ivorian bacilliform virus.

(D. Fargette[2], I. M. Roberts, B. D. Harrison)

Detection of parsnip yellow fleck virus (PYFV) antigen in ultrathin sections of infected leaves [PU 25(e)]

Leaf pieces of *Nicotiana clevelandii* plants infected with PYFV isolate P-121, or *Spinacia oleracea* infected with isolate P-121 or isolate A-421 were embedded, sectioned and, after immunogold labelling, examined to determine the distribution of PYFV antigen in cells. Gold labelling was done with PYFV immunoglobulin which had first been absorbed with protein from healthy plants. Almost all the gold label was confined to the inclusion bodies induced by infection (*Ann. Rep. 1972*, 66) and, within them, to areas of amorphous material which are distinct from the tubules and granular bodies, the two other major constituents. Specific but less dense labelling was also found over nuclei, cell walls and cell wall outgrowths in cells containing inclusion bodies. However, virus particles

[1]Short-term Appointment
[2]Visiting Worker
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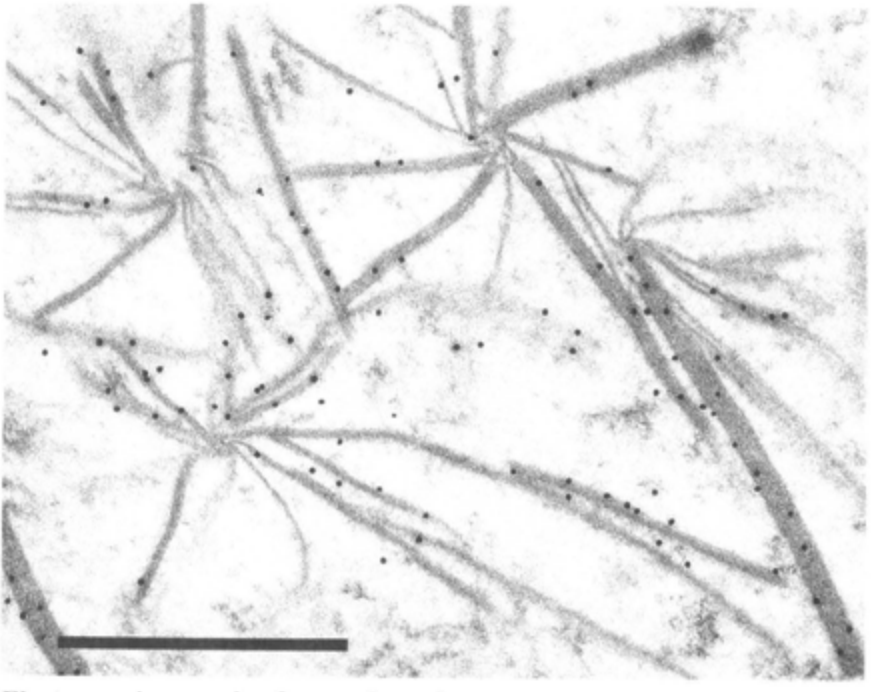
found within tubules in the cell wall outgrowths were not labelled, perhaps because they were shielded by the tubule membrane, or were below the surface of the section and hence not available to the antibody/gold probe.

(C. Fasseas[1], I. M. Roberts, A. F. Murant)

Detection of narcissus yellow stripe (NYSV) and other potyviruses with antiserum to a non-structural viral protein [PU 11(a)]

Investigations on narcissus yellow stripe disease, which was reproduced by inoculating virus-tested narcissus plants using aphids taken from a naturally diseased plant as the virus source, failed to confirm the claim by other workers that the disease is caused by a virus with particles c. 750 nm long. Instead only particles 650 nm long, and identified serologically as narcissus latent carlavirus, were found. However, examination of thin sections of leaf cells of the experimentally infected plants revealed pinwheel cytoplasmic inclusions (Fig. 5), typical of a potyvirus. Because no

**Figure 5**



**Electron micrograph of a section of a narcissus leaf cell infected with narcissus yellow stripe virus, showing cross-sections of viral cytoplasmic inclusion bodies (structures with radiating arms) which are immunogold-labelled (black dots) using antiserum produced to purified cytoplasmic inclusion protein. Bar represents 500 nm.**

[1]Visiting Worker

antiserum to NYSV particles was available, an antiserum to NYSV cytoplasmic inclusion (CI) protein was prepared and evaluated for detecting the virus in ELISA. Following unsuccessful attempts to purify the CI bodies or protein by published methods, a preparative procedure was devised which, when applied to leaf tissue from narcissus plants with yellow stripe symptoms, provided preparations containing lamellar fragments showing the periodicity typical of potyvirus CI bodies. In SDS-PAGE of the proteins in these preparations, a major band of mol. wt. 72 K was produced that was not detected in control preparations made from uninfected narcissus plants. Antiserum made to this protein, excised from polyacrylamide gels, reacted specifically with CI bodies in ultrathin sections of virus-infected cells (Fig. 5) and reacted only with the mol. wt. 72 K band in immunoblots of proteins in CI preparations. In ELISA, the antibodies reacted with leaf extracts from yellow-stripe diseased plants of four narcissus cultivars but not with extracts from comparable symptomless plants. In dot-blot ELISA, specific reactions were dependent on including Tween-20 in the extraction buffer. One interpretation of the failure to detect particles of the length (750 nm) claimed to be typical of NYSV is that the CI bodies found are associated with narcissus latent carlavirus. However, in serological tests with seven definitive potyviruses, the CI antiserum reacted with extracts of plants infected with bean yellow mosaic and iris mild mosaic potyviruses: thus the CI protein is serologically related to that of potyviruses.

When the preparative procedure used with NYSV-infected narcissus was applied to four definitive potyviruses (alstroemeria mosaic, potato Y, tulip chlorotic blotch and turnip mosaic) infecting various *Nicotiana* spp., a putative CI protein band was detected by SDS-PAGE in preparations from each source, suggesting that the method is generally applicable. This is further supported by the specific reactions obtained in dot-blot ELISA with an antiserum produced to the putative CI protein of alstroemeria mosaic virus. However, in this instance, and in contrast to the NYSV-CI antiserum, the alstroemeria mosaic virus CI antiserum contained antibodies only to denatured CI protein and it was necessary to use SDS-treated antigen to obtain reactions.

(W. P. Mowat, S. Dawson, G. H. Duncan)

Health of narcissus stocks derived from virus-tested (VT) material [PU 11(b)]

When grown in the field, VT narcissus stocks become classified first as Foundation Stock, and later, when they are grown for commercial production, as one or other of two lower grades (Elite Stock and Special Stock) in the DAFS Narcissus Certification Scheme. For Elite Stock, the minimum isolation distance from non-VT stocks is 50 metres whereas for Special Stock it is 1 metre. In 1988 the first assessment was made of virus incidence in examples of the oldest of these stocks, then in their third

season of multiplication. Two Elite Stock plantings, one of cv. Carlton and the other of cv. Sempre Avanti, and a Special Stock planting of Carlton, were indexed by ELISA for narcissus latent carlavirus, narcissus mosaic potexvirus (NMV), narcissus tip necrosis tombusvirus and narcissus yellow stripe potyvirus. Of 500 plants sampled in each stock, none from the Elite Stocks was infected whereas three plants from the Special Stock were infected with NMV. This confirms previous observations (*Ann. Rep. 1986,* 171; *Ann. Rep. 1987,* 185) of field spread of NMV when virus sources are close. The results also suggest that an isolation distance of 50 metres may give protection from this virus, the natural mode of spread of which is unknown, as well as from the other three viruses, two of which are aphid-transmitted.

(W. P. Mowat, S. Dawson)

Previously undetected virus in cv. Himalaya Giant blackberry [PU 9(d)]

When scions of Himalaya Giant blackberry were grafted on *Rubus macraei* to detect rubus yellow net virus (RYNV), a severe leaf curling symptom developed, usually within 4 wk. These symptoms were quite unlike the faint vein netting symptom associated with RYNV infection in *R. macraei.* Further tests showed that the graft-transmissible agent responsible for the leaf curling was latent in stocks of Himalaya Giant that were free from all previously described *Rubus* viruses.

(A. T. Jones)

Properties of a satellite-containing culture of arabis mosaic virus (AMV) [PU 9(d)]

Following the successful use of a satellite RNA of cucumber mosaic virus to inhibit the development of symptoms caused by this virus in tobacco, work was started to ascertain the possible usefulness of a satellite RNA of AMV for decreasing the damage caused by this virus in sensitive cultivars of raspberry and strawberry. In preliminary studies, the effects of a satellite-containing and a satellite-free culture of an ash isolate of AMV (supplied by J. I. Cooper[1]) on herbaceous test plants were compared. Most *Nicotiana* species inoculated with the satellite-free culture developed distinct necrotic or chlorotic symptoms in inoculated and/or systemically infected leaves, whereas comparable plants inoculated with the satellite-containing culture were infected symptomlessly. By contrast, *Chenopodium amaranticolor, C. murale* and cucumber each developed severe systemic symptoms when inoculated with either AMV culture. Thus, as with other species of virus satellite RNA, the satellite-mediated amelioration of virus symptoms is host specific.

(A. T. Jones)

[1]Dept. of Plant Sciences, University of Oxford

Light and electron microscopy of June Yellows (JY)-affected strawberry [PU 9(g)]

Light and electron microscopy were used to examine the effects of JY on leaf cells. Light microscopy of cryo-sections of leaves of cv. Tyee strawberry with a severe form of JY, characterised by white streaks, showed an almost total breakdown of cell organisation in the white streaked areas; such areas were discrete, and confined to regions between vascular bundles. Light microscopy of resin-embedded sections stained with basic fuchsin followed by alkaline methylene blue showed similar cell disruption in leaves with bright yellow streaks of the cultivars Bogota, Tyee and Cambridge Favourite, whereas cells in leaves of normal Cambridge Favourite plants did not show these abnormalities. The palisade cells were generally more damaged than spongy mesophyll cells. Staining was diffuse and irregular in the damaged cells. In JY-affected Cambridge Favourite, irregularly shaped cells in the lamina showed invaginations of the cell walls. Similarly stained sections of leaves of Cambridge Favourite and cv. Dominil strawberry with faint JY symptoms again showed cell disruption and this increased from the abaxial to the adaxial surface.

Electron microscopy of all JY-affected material showed that the cells contained greatly swollen nuclei, chloroplasts and mitochondria leading, in some instances, to a complete or partial loss of the cell vacuole. In the most severely affected areas, the chloroplast grana had separated into individual thylakoid strands and the plasmalemma was detached from the cell wall, indicating possible plasmolysis. Cytoplasmic vesicles were more commonly observed in cells of JY-affected plants than in those of healthy plants. Vesicles associated with the plasmalemma had a more densely stained interior than the surrounding cytoplasm. Ribosomes appeared to be in higher concentration in JY-affected plants, except in Bogota. No virus-like particles were observed, but the occurrence of cell wall outgrowths, enlarged nuclei and hypertrophied mitochondria and chloroplasts, features commonly found in virus-infected plant cells, may indicate that a pathogenic agent is involved in JY.

(C. A. Watkins[1], I. M. Roberts, A. T. Jones)

Virus indexing of Rubus cultivars and selections [PU 9(e)]

During the year, 47 breeders' selections from the *Rubus* breeding programmes at SCRI and IHR (East Malling) were indexed by ELISA for infection with raspberry bushy dwarf virus (RBDV) and black raspberry necrosis virus (BRNV). None was infected with RBDV but four SCRI selections were infected with BRNV. More extensive virus tests were made on five advanced selections due to be released commercially, and virus-free mother plant material of each was identified.

[1]Short-term Appointment

During the past 3 years more than 80 samples of commercial *Rubus* plants have been received at SCRI to test for virus infection, mostly from England and Wales. Most of the infected material contained nepoviruses; 11 samples from Scotland contained raspberry ringspot virus whereas material from England and Wales contained arabis mosaic (15 samples), strawberry latent ringspot (2) and tomato black ring (2) viruses.

(A. T. Jones)

Virus indexing of Ribes and miscellaneous berry fruits [PU 9(h)]

The work started in 1987 to index commercial *Ribes* cultivars and breeders' selections for viruses was continued. In addition to seven cultivars of special commercial interest that are being tested, 10 selections from the SCRI breeding programme, and 15 imported selections of *Ribes* spp., were also indexed.

During the year, imported plants of *Aronia melanocarpa, Sambucus nigra,* three *Rosa* spp., three *S. canadensis* cultivars and four *Hippophae rhamnoides* cultivars were tested for virus infection by inoculation of sap to cucumber, *Chenopodium quinoa* and *Nicotiana clevelandii* leaves. The only infection detected was in one cultivar of *S. canadensis,* which contained elderberry latent virus.

(A. T. Jones)

Scanning electron microscopy of legume root nodules [PU 25(h)]

In collaboration with E. James[1], a cryo-trimming/freeze-drying technique (*Ann. Rep. 1987,* 194) was applied to soybean root nodules to obtain information on their internal structure relevant to the inward diffusion of oxygen. Before freeze-drying, the nodules were cryo-trimmed to expose a central region, in which *Rhizobium* bacteria could be seen readily. Such specimens showed far less collapse of cell walls than those which were fixed and critical-point dried. Intercellular spaces in the cortex were sharply delineated, enabling possible pathways for the supply of oxygen to the *Rhizobium* bacteria to be identified.

(G. H. Duncan)

[1]Department of Biological Sciences, University of Dundee

# SCOTTISH AGRICULTURAL STATISTICS SERVICE

R. A. KEMPTON

The Scottish Agricultural Statistics Service (SASS) is now well established at all four centres following five further statistical appointments during the year.

*New statistical methods and applications*

Substantial progress was made in setting up four new research areas in image analysis, chemometrics, environmental studies and food technology.

In image analysis, the main sources of SASS data are medical imagers, satellite sensors and microscopes. Methods were developed for estimating sheep carcass composition from X-ray computed tomographs, and human fat percentages from nuclear magnetic resonance images. A new type of satellite data, synthetic aperture radar, was studied in collaboration with the remote sensing group of Instituto Nacional de Investigaciones Agrarias, Madrid, with the help of British Council funding. Measures of image texture were found to be of use in identifying land usage. A PC-based image display system was set up.

In chemometrics, attention was directed towards the use of principal components in analysing near-infrared spectra. This in turn has led to new methods of standardising spectra for particle size which are now in use at SCRI.

In environmental research, work was initiated jointly with the MLURI Land Use Division to monitor the effects of the scheme for Environmentally Sensitive Areas. A system for relating aerial photographs to ground observations was developed for the Division and will be used as part of their work with SDD. Methods are being developed for monitoring the impact of set-aside on vegetation, in collaboration with NSCA. In a project funded by ITE, Banchory, new methods are being used for estimating survival rates of seabirds to provide a more sophisticated approach to detecting environmental change.

In food technology, work has started on developing statistical methodology for sensory experiments, particularly for analysing subjective scores from tasting panels, in collaboration with Royal Veterinary and Agricultural University, Copenhagen. This work is centred on HRI and the methods are being used on an EEC-funded project for developing a non-alcoholic cream liqueur. Another large scale project with ESCA involves a comparison of beef from organically and conventionally reared cattle.

Research on statistical methods for field experiments has included development of efficient row and column designs with two replicates. These designs are potentially of great benefit when testing large numbers of genetic lines and are being used in pilot studies at SCRI and in the sugar cane breeding programme of Copersucar, Brazil.

*Statistics training for scientists*

Five 2-day training courses were prepared and presented to scientists in SARIs and SAC. The courses are based around two computer packages, Minitab and Genstat 5, and have ranged from elementary exploratory and inferential methods, through analysis of variance and regression, to the handling of multivariate data. Provision of hands-on experience of data analysis in a computing laboratory, allows statistical ideas to be presented to scientists in an intuitive and appealing way.

A statistical consortium comprising SASS, University of Edinburgh Department of Statistics, University of Edinburgh Medical Statistics Unit and the Statistics Group of Institute of Occupational Medicine was set up in the summer to run commercial courses under the title Edinburgh Statistics Courses. SASS ran two courses, Introduction to Genstat 5 and Basic Statistics for Biologists using Minitab, as part of the consortium's programme.

*Statistical computing*

Genstat 5 was implemented on the PRIME computer. This was a major task carried out by SASS for the Numerical Algorithms Group, who distribute the Genstat package for IACR Rothamsted Experimental Station. A new version of the Residual Maximum Likelihood Program was produced for desk-top microcomputers. This package is used in many research organisations throughout the world and was distributed to 25 sites during the year. A number of projects involving the development of expert systems were started during the year. These include a joint project with Agricultural University, Madrid on automated procedures for discriminating plant material by shape.

*Statistical support for SCRI*

Despite the shortage of statistical staff during the year, good progress was made with several collaborative projects.

An established mathematical model describing the population dynamics of the potato cyst nematode has been extended, to allow more detailed study of interaction with the potato plant and the effect of different control strategies in reducing yield loss. Validation of the model has been established using field data for six potato cultivars with varying levels of resistance and tolerance to nematode damage. The model can be used to investigate the effect on nematode population densities of various rotations of different potato cultivars and non-host crops.

In an unreplicated field trial, an analysis of yield variation among check plots of two established spring barley cultivars was used to indicate environmental differences, including soil fertility. The data were used successfully to adjust yields of the genotypes in trial for environmental differences down and across the field. Adjustment was made on the basis of test plot yield being proportional to the weighted mean for the three nearest check plots, with weights inversely proportional to their distances from the test plot.

The near-infrared work with the Chemistry department was dominated by the negotiations with the Pacific Scientific Company, Silver Spring, USA to market SCRI principal component software. This involved substantial rewriting of the program to fit into the Pacific Scientific's own Near Infrared package.

*Statistical support for other organisations*

Details of collaborative SASS work with other SARIs and SAC can be found in the annual reports of these organisations. In addition SASS provides support for the statutory and regulatory work carried out by DAFS Agricultural Scientific Services and for statutory responsibilities of UK cultivar testing authorities.

# ESTATE DIVISION

W. I. A. JACK

Once again extremes of the weather resulted in a year not without its problems. In most but not all instances crops grew well but not outstandingly, resulting in yields slightly higher than 1987. Field beans, raspberries, potatoes and winter barley were the least satisfactory.

In anticipation of the implementation of the Control of Pesticides Regulation 1986 Part 3, most of the Division's staff were trained, examined and gained the obligatory certificate of competence to enable compliance with the new statutory regulations for the safe handling and application of pesticides to on- and off-station trials.

## Farm Crops

Farm crops grown in 1988 included 56.7 ha spring barley, 21 ha grass, 11 ha winter barley, 4 ha field bean, 1.2 ha potato, 2.1 ha winter wheat, 1 ha turnip and 28.7 ha fallow; this is a decrease of 2.7 ha from 1987.

Sowing of spring barley cultivars Camargue, Esk and Natasha which commenced on 28 February into fair seedbed conditions was completed with few interruptions on 11 March: germination and plant stand was satisfactory. Outbreaks of mildew (*Erysiphe graminis*) required fungicide sprays. Combining started on 16 August but progress was slow as a result of the poor weather conditions and was finally completed on 30 September. The average yield was up 0.5 t/ha on the previous year with individual cultivar yields of 4.6 t/ha Camargue, 6.5 t/ha Esk and 4.1 t/ha Natasha. Despite the poor growing conditions experienced throughout the year, grain samples in general were fair with 62% of the crop meeting malting market standards. Winter barley cv. Magie sown in the autumn of 1987 was potentially a good crop but gale force winds on 25 July blew off about 60% of the heads: combining started on 4 August with a final yield of 3.02 t/ha of feeding quality grain. Winter wheat cv. Galahad sown in November of 1987 did not survive in the poor land conditions, with only 20% of the area sown surviving to harvest, giving an exceptional yield of 12.8 t/ha of bold feeding quality grain.

Field bean cultivars Alfred and Herz Freya sown into excellent seedbeds on 23 February germinated poorly, which together with atrocious harvesting conditions resulted in one of the worst yields, 2.1 t/ha, recorded at the Institute.

Grass grew away slowly in the early part of the spring, but made rapid progress in June and hay was secured in excellent condition. Cutting started on 10 June and baling was completed by 17 June, the yield of 9.5 t/ha was up 3.4 t/ha on the previous year.

The protracted harvest and wet weather hindered the routine programme of stubble cleaning, straw chopping and incorporation. However sub-soiling and ploughing was done when conditions were suitable, and was completed by the end of the year.

Estate work was confined to field drainage repairs, the completion of the boundary fence at Gourdie farm and the planting and maintenance of windbreaks.

(R. W. Reid)

## The Murrays Farm

The weather throughout the year was extremely variable, crops grew moderately well with resulting yields being average. Unfortunately severe weather stress occurred when crops were most vulnerable, the land was wet and puddled at potato emergence, producing compaction and capping. Weed emergence in particular was unpredictable, making decisions about herbicide application extremely difficult, and sometimes resulting in very weedy crops.

Spring barley cultivars Camargue, Doublet and Tyne were drilled in March/April. Conditions were dry and cold during tiller initiation and consequently head density was less than ideal. Fungicide application was required for mildew and *Rhynchosporium* control.

Harvest commenced in late August but despite the poor season yields averaged 5.1 t/ha. 16 ha of winter wheat cv. Mercia was grown, yielding poorly at 8.6 t/ha: disease control was not a problem but late emerging poppies made the crop look very untidy.

20 ha of grass was let for grazing and 11 ha was cropped for hay. 6.5 ha of swedes were contract grown for the shopping trade.

(I. M. Chapman)

## Field Experiments

There was a total of 330 field experiments and off-station trials. The crops grown included 11 ha raspberry, 5.5 ha black currant, 2.25 ha strawberry, 1.5 ha black- and hybridberry, 20 ha cereal, 9 ha brassica, 4.5 ha potato, 0.65 ha field bean, with a miscellany of minor crops occupying a further 7 ha.

In comparison with 1987, there was very little difference in the total area occupied by all trials on-station. There was, however, a significant reduction in the area of field bean trials, while the increase in the area of minor crops was, in part, attributable to the establishment of trials for the assessment of candidate novel fruits.

Trial facilities for ESCA were provided at No. 2 holding, East Pilmore, to enable some of ESCA's land at Castle Huntly to be rested for a year.

The Press and Open Days on 8 and 9 July provided an opportunity for several areas of trials to be showcases for the field work of the Institute. resentation and maintenance standards were regarded highly by the visitors.

The gale force winds and deluge of rain on 25 July had devastating effects on some large areas of raspberry trials. These trials were heavily laden with fruit and all posts were broken and the plantations flattened to the ground. Many trial results were written-off for 1988. Brassica and cereal trial areas were fortunate and escaped with little or no severe damage.

The servicing of the trials for annual crops, including brassica, cereal and potato, proved to be significantly more complex in 1988. The number of trials with special requirements and/or treatments increased, plans and the inputs required were changed, and additional submissions were still being made in the early summer months.

(G. Wood)

*Soft Fruit*

Reasonably mild weather enabled the winter fruit work to be completed on schedule. An area of novel fruits was planted in the spring.

Fruit picking of strawberries commenced on 29 June and it proved to be a short season. Raspberry picking started on 30 June which is very early for mid-season cultivars. Yields were severely hit by the torrential downpours and gale force winds of 25 July which resulted in some 2.5 t/ha of fruit being blown to the ground and the remaining canes and fruiting laterals being badly damaged. The first black currants were picked on 7 July with the bulk of the fruit being harvested by machine this year for the first time. On 27 July, blackberry, Tayberry, and blueberry picking started. The blueberry crop was disappointing this year probably due to the severe pruning of the bushes which had been undertaken in the spring.

Autumn work was well ahead of schedule due to a slight reduction in number of soft fruit experiments and, as last year, the unseasonably mild weather.

(D. S. Petrie)

*Brassica*

After reasonable weather for the preparation of seedbeds and sowing, a long dry spell coincided with a heavy incidence of attacks from successive generations of cabbage root fly. Pigeon damage was also quite prevalent during the dry weather despite various types of scarers being used.

The severe gales caused some lodging of kale and leaf damage to rape but the latter was quickly outgrown.

Clubroot was widespread in the rape, patchy in the swede and turnip areas, but practically non-existent in the kale.

Harvest conditions were generally good and completed in reasonable time.

(A. Pirie)

*Cereal and field bean*

Winter cereals occupied two separate field areas, with one being much later drilled in poorer conditions than the other. The mild weather allowed the trials to overwinter well.

Spring cereal sowing started at the beginning of March and progressed more easily than in past years. Weather and soil conditions were favourable and the soil was worked down with a non-powered harrow to make an excellent seedbed. Weed control in the spring trials field was the best achieved so far. In the spring-cereal stocks fields, however, infestations of couch grass, thistles and potato groundkeepers were a continual problem. In the winter trials, sparrow damage necessitated the erection of netting and 'humline' deterrents. The storms at the end of July damaged nets and cages but the crop was not seriously affected.

Harvesting started at the beginning of August with winter barley, and the entire winter cereal trials areas were harvested by 24 August. The spring cereal trials harvest started on 22 August and progressed right through September: plot weights were excellent.

Winter cereal trials sowing started in September in reasonable conditions but ran into bad weather in October. The continuing mild weather, however, meant that they entered the winter in fine fettle.

Some machinery modifications have significantly improved cereal trials operations. Most of the seeders have been converted to combine drill seed and fertilizer, and centre-line markers have been fitted to all seeders to assist tractor positioning.

The field bean trials were much smaller than in previous years, and apart from being sown rather late presented no problems.

(D. G. Pugh)

*Potato*

1988 will be remembered for being a year of contrasting and unseasonable weather conditions. Planting was delayed until the last week of April. In May and June soil temperature and moisture were ideal for potato growth and emergence was rapid and even. Most cultivars had closed the drills by early July, thus enhancing already good weed control.

Irrigation was requested between June 8 and July 19. From then onwards it was one of the wettest summers on record.

Blight control sprays started on 6 July and continued until late September. Eight sprays were applied and yet there was still a significant number of tubers in store which were infected by blight.

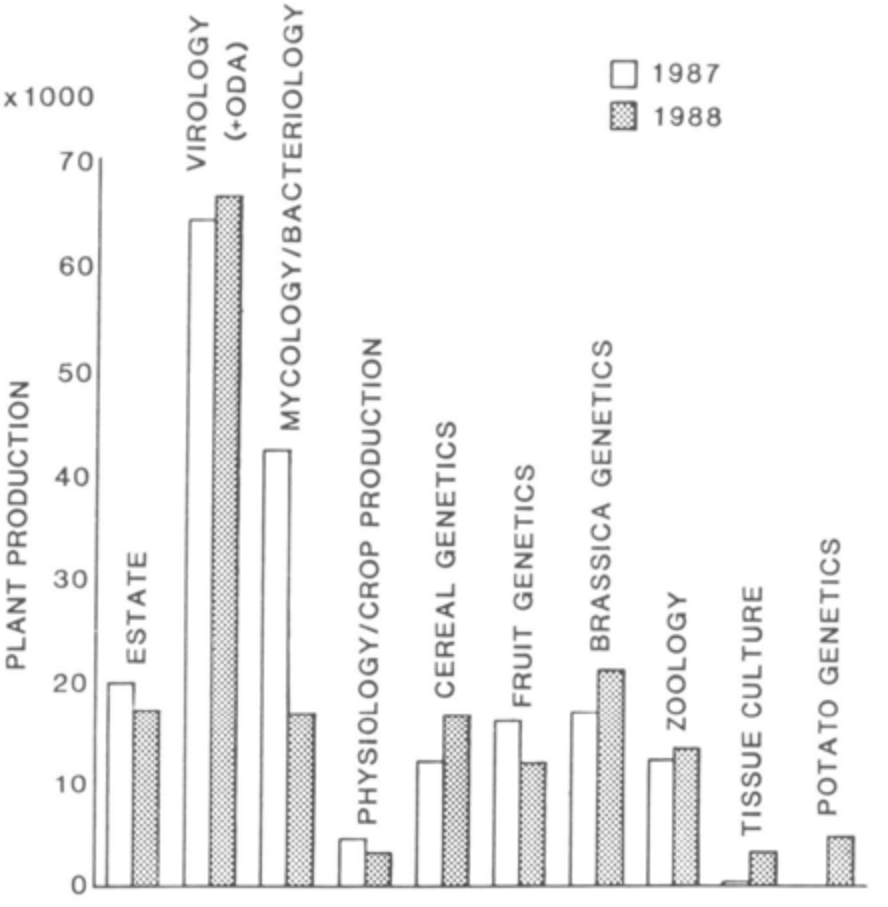
Wet, heavy ground made harvesting plots a long and laborious task, and with the crop being lifted in such conditions storage and grading proved extremely difficult.

(C. C. Carrie)

## Glasshouses

Production of plants for the scientific departments fell in 1988 to a total of 175,153, despite an increase in the number of job requests that were processed. Changes in departmental requirements compared with 1987 are shown in Figure 1.

**Figure 1**




**Plant usage by departments**

During the year, staff rebuilt three small Cambridge houses into a single unit although the services still have to be installed. Six tunnel structures were erected, three covered with polythene and three with Nicofence netting. Another phase in the building programme was completed with the commissioning of four seedling houses for the Potato Genetics Department. Efficient use of floor area has been achieved by the installation of large roller benches, which together with a fully automated irrigation system,

should ensure that labour requirements are minimised. An additional wing for the Mycology and Bacteriology Department was completed at the end of the year and should be available for use early in 1989.

The numbers of cultivars and seedlings maintained under the nuclear stock scheme were 214 *Rubus*, 32 *Ribes* and approximately 200 clones of narcissus. *Rubus* root was supplied to SNSA to produce 8000 pot plants for the first stage of nursery production. Root material from the SCRI and IHR breeding programmes was also dispatched to several foreign research centres.

(P. A. Gill)

# INFORMATION SERVICES

R. J. A. EXLEY

Acceptance by DAFS of the Report of the Management Audit Unit team, which inspected the work of Information Services in June 1987 (*Ann. Rep. 1987,* 205), was received in September this year.

The contribution made by service staff, seldom lends itself to formal reporting, and mostly is concealed in the results of research by scientists; for Visual Aids staff the illustrations in published scientific papers or displays are also a manifestation of their efforts. However the Press Day and Public Open Day held this year and attended by almost 1700 people, provided the opportunity for the photographic, graphic and illustrative skills to be appreciated by a much wider audience.

## LIBRARY

By the end of 1988, all library facilities were being transferred from Pentlandfield to Invergowrie. The stock and equipment were transferred in bulk and stored at Invergowie in preparation for detailed checking and recataloguing as resources permit.

Few of the Pentlandfield books could be shelved immediately at Invergowrie. Universal Decimal Classification (UDC) system, used at Pentlandfield and Invergowrie, provides for many subjects a choice of numbers according to the needs of the library users, and in many instances the two libraries had chosen different numbers. Also, the 1985/1988 edition of UDC, which accommodates more appropriately the new range of scientific methods in use at SCRI, is better suited to the needs of the Library than the 1961 edition previously in use. For these reasons an enormous number of books required to be reclassified, and the work started in October.

The subject of computerisation of library services is the subject of on-going discussion, and demonstrations of several systems were attended or organised. However, no decision has yet been made because of the high cost involved, and the need to await modification of the better systems.

In 1988 there were 2031 inter-library loans, which is a 10% increase compared with 1987. There were 1124 internal loans and 135 computerised literature searches compared with 1095 and 81 respectively for 1987.

The Librarian attended the May and October meetings of the Scottish Agricultural Librarians' Group, and in March, together with the Administrative

Officer, attended a meeting on New Technology for Libraries at the Scottish Council for Educational Technology.

(U. M. McKean)

## VISUAL AIDS

The continuing increase in visual aids production was again evident in 1988.

| | PHOTOGRAPHY | | | | | GRAPHICS | |
|---|---|---|---|---|---|---|---|
| | Jobs | Colour | Monochrome | Diazo | EM/prints | Jobs | Graphics |
| 1987 | 2284 | 9656 | 11703 | 979 | 2184 | 298 | 2534 |
| 1988 | 2498 | 9598 | 13282 | 513 | 2318 | 549 | 5402 |

Cine and video time-lapse recordings of various subjects were undertaken throughout the year.

In January production began for the Open Day in July. Fifty exhibits comprising over 300 display panels containing colour prints, graphics, captions and titling were produced, together with a 20 minute 'dissolve' slide presentation, with taped commentary, entitled 'SCRI: the organisation and the work'. A video tape was also produced to show equipment and techniques used to record the movement of fluorescent molecular probes in plant cells and to determine their rates of transport.

T. G. Geoghegan and G. Martin attended the 7th AFRC Photographers and Graphics Officers Conference at University of Warwick, 14-15 September.

(T. G. Geoghegan)

# SCOTTISH SOCIETY FOR CROP RESEARCH

## *Directory for 1988/89*

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## *Report by the Committee of Management*

The Committee of Management met on three occasions (10 March, 28 June and 8 November) during 1988 for the transaction of Society business.

There were also meetings of the Crop Sub-Committees at various times throughout the year.

During the year the Committee authorised the payment of grants for travel as listed below:–

From the General Fund:

(i) £200 to B. Boag (SCRI Zoology Department) attending the XIX International Symposium of the European Society of Nematology, Uppsala University, Sweden in August.

(ii) £500 to D. L. Trudgill (SCRI Zoology Department) attending the V International Congress of Plant Pathology, Kyoto, Japan in August.

(iii) £500 to N. L. Innes (SCRI Cereal Genetics Department) attending the Eucarpia Congress in Genetic Manipulation in Plant Breeding at Elsinore, Denmark in September.

Full reports of these visits are available from the Secretary.

This was a memorable year for the Society as a result of the Open Day (Preview) held by the Institute on Friday 8 July 1988 when members of the Society were invited to attend and visit the exhibits explaining much of the Institute's work, and to talk to staff and visit many of the research facilities. Various Committee Members assisted at the Society display during the Preview and the public Open Day.

Two Newsletters were produced during the year in July and November which were full of interesting snippets concerning the research work of the Institute.

**Figure 1**


**Recruiting new members at the SCRI Open Day**

SCRI Bulletin No 7 (December 1987)

*Soft Fruit*



The members of the Committee who will retire by rotation with effect from the date of the Annual General Meeting held in 1989 are Messrs D. Craib, C. K. Frampton, J. R. Love and D. Morrison.

As at 31 December the membership of the Society stood at 323.

Mylnefield

Taken as a whole the year was dull and wet with only a few spells of good weather. Two striking features of the year were the unusual gale on 25 July which caused damage to trees and crops, and the weather during December which was dry and warm for the time of year.

*Temperature*

Air and soil temperatures were below average in July but throughout the rest of the year they were at or above average. In the quarter to March average temperatures were more than 1°C higher than average and in December were remarkable at 3.1°C above average. The highest daily maximum that month was 13.5°C on the 28th and the mean maximum for the last week of the year was 11.4°C.

*Rainfall*

The months of April, July and August were very wet with 185% of average rainfall and the only period of the growing season that was noticeably dry was June (44% of average). December, too, was dry with only 25% of average rainfall.

*Sunshine and Solar Radiation*

Despite the dry conditions in June the duration of bright sunshine was close to average and solar radiation was only 8% above average. July and October were particularly dull with hours of sunshine being 23 and 25% below average respectively. Over the growing season total solar radiation was only 4% below average.

*Wind*

June and November were quiet months with run-of-wind some 30% less than average and in March and April winds were 22% below average. In contrast July was windy and on 25 July a gale gusting to 95 km/h and a mean windspeed of 48 km/h caused damage to crops and uprooted or snapped the trunks of trees in full leaf. On 11 and 26 July also, the mean windspeeds were between 24 and 30 km/h.

*Potential Evaporation*

Throughout the growing season, even in June, potential evaporation was at or well below average.

(D. K. L. MacKerron, G. Dunlop)

MYLNEFIELD

| Month | Temperature: Daily air maxima Mean °C | Daily air maxima DFA * | Daily air minima Mean °C | Daily air minima DFA * | 0.1m Soil Mean °C | 0.1m Soil DFA * | 0.3m Soil Mean °C | 0.3m Soil DFA * | Accumulated degree days Above 6°C | Accumulated degree days Below 6°C | Days ground frost | Potential evap-oration mm | Rainfall Total mm | Rainfall DFA * | Bright sunshine hours Total | Bright sunshine hours DFA * | Mean daily solar radiation mWh/cm² | Windspeed Mean km/h | Windspeed DFA † |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January | 6.6 | +1.1 | 1.4 | +1.4 | 2.5 | +1.0 | 4.3 | +1.8 | 11.6 | 73.8 | 29 | 5.4 | 97.3 | +34.5 | 58.3 | + 5.2 | 42 | 11.5 | −1.4 |
| February | 7.1 | +1.5 | 1.8 | +1.8 | 2.4 | +0.8 | 3.9 | +1.3 | 16.2 | 62.2 | 26 | 19.9 | 31.0 | −17.0 | 84.3 | +12.7 | 111 | 14.6 | +2.4 |
| March | 8.8 | +0.9 | 1.8 | +0.1 | 3.8 | +0.5 | 5.0 | +0.7 | 34.3 | 56.8 | 23 | 35.4 | 60.0 | +10.1 | 143.7 | +38.4 | 241 | 12.2 | −2.6 |
| April | 10.9 | −0.1 | 4.3 | +1.0 | 7.6 | +1.3 | 8.3 | +1.4 | 66.3 | 19.3 | 8 | 47.5 | 73.2 | +33.1 | 113.7 | −43.7 | 224 | 10.3 | −3.9 |
| May | 14.4 | +0.7 | 6.9 | +1.1 | 11.4 | +1.2 | 10.8 | +0.7 | 146.8 | 2.9 | 3 | 81.4 | 41.5 | −14.1 | 177.0 | − 5.2 | 457 | 11.2 | −1.3 |
| June | 18.2 | +1.3 | 9.7 | +1.0 | 15.9 | +2.0 | 14.2 | +0.7 | 237.4 | 0.2 | 1 | 85.1 | 22.3 | −28.0 | 180.4 | + 1.6 | 527 | 7.9 | −3.9 |
| July | 17.3 | −1.2 | 10.4 | +0.2 | 14.5 | −0.8 | 14.9 | −0.2 | 242.8 | 0.2 | 0 | 78.9 | 113.0 | +51.5 | 135.4 | −39.9 | 408 | 11.9 | +1.2 |
| August | 18.0 | −0.3 | 10.7 | +0.6 | 14.2 | −0.2 | 15.2 | +0.3 | 257.7 | 0.0 | 0 | 76.2 | 122.9 | +57.3 | 151.8 | − 2.0 | 368 | 10.9 | +1.1 |
| September | 16.2 | +0.3 | 8.3 | −0.3 | 11.6 | +0.1 | 13.3 | +0.6 | 190.5 | 2.5 | 1 | 50.4 | 54.5 | − 8.6 | 137.8 | +19.7 | 246 | 11.6 | +0.3 |
| October | 12.0 | −0.5 | 6.2 | 0.0 | 8.5 | +0.4 | 10.7 | +1.0 | 109.5 | 15.5 | 8 | 18.0 | 107.7 | +46.0 | 72.5 | −18.2 | 103 | 11.7 | +0.1 |
| November | 8.4 | +0.1 | 2.1 | −0.1 | 4.1 | 0.0 | 6.8 | +0.9 | 28.8 | 52.0 | 22 | 5.1 | 69.1 | +13.1 | 87.6 | +20.6 | 68 | 8.4 | −3.7 |
| December | 9.6 | +3.3 | 3.7 | +2.9 | 4.6 | +2.3 | 5.9 | +2.3 | 50.7 | 30.1 | 16 | 9.3 | 17.7 | −52.1 | 52.4 | + 8.5 | 30 | 14.6 | +1.9 |

*Deviation from 1954-1983 average

†Deviation from 1959-1983 average

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# LIST OF ABBREVIATIONS

*Organisations*

| | |
|---|---|
| AAB | Association of Applied Biologists |
| ADAS | Agricultural Development and Advisory Service |
| AFRC | Agricultural and Food Research Council |
| AFRS | Agricultural and Food Research Service |
| AGC | Agricultural Genetics Company |
| ASS | Agricultural Scientific Services (DAFS) |
| ATB | Agricultural Training Board |
| BBC | British Broadcasting Corporation |
| BSBP | British Society of Plant Breeders |
| BTG | British Technology Group |
| CIP | International Potato Center — Peru |
| DAFS | Department of Agriculture and Fisheries for Scotland |
| DANI | Department of Agriculture for Northern Ireland |
| EAPR | European Association for Potato Research |
| EEC | European Economic Community |
| EMBO | European Molecular Biology Organisation |
| EPPO | European Plant Protection Organisation |
| ESCA | East of Scotland College of Agriculture |
| HDC | Horticultural Development Council |
| HGCA | Home Grown Cereals Authority |
| IPCS | Institution of Professional Civil Servants |
| ITE | Institute of Terrestrial Ecology |
| NATO | North Atlantic Treaty Organisation |
| NIAB | National Institute of Agricultural Botany |
| NPTC | National Proficiency Test Council |
| NSCA | North of Scotland College of Agriculture |
| ODA | Overseas Development Administration |
| PMB | Potato Marketing Board |
| RHAS | Royal Highland and Agricultural Society of Scotland |
| SAC | Scottish Agricultural Colleges |
| SASS | Scottish Agricultural Statistics Service |
| SARI | Scottish Agricultural Research Institutes |
| SCRI | Scottish Crop Research Institute |
| SDA | Scottish Development Agency |
| SDD | Scottish Development Department |
| SEB | Society for Experimental Biology |
| SERC | Science and Engineering Research Council |
| SNSA | Scottish Nuclear Stocks Association |
| SSCR | Scottish Society for Crop Research |
| UC | University of California |
| UK | United Kingdom |
| USA | United States of America |
| SDA | United States Department of Agriculture |
| WSC | The West of Scotland College |

*Miscellaneous*

| | |
|---|---|
| CASE | Cooperative Awards in Science and Engineering |
| DM | Dry matter |
| DUS | Distinctness, uniformity and stability |
| EHF | Experimental Husbandry Farm |
| ELISA | Enzyme linked immunosorbent assay |
| EMAS | Edinburgh Multiple Access System |
| HPLC | High pressure liquid chromatography |
| IFS | Increased Flexibility Scheme |
| NFT | National Fruit Trials |
| NIR | Near infra-red |
| NLT | National List Trials |
| RCCA | Research Council Co-operative Award |
| SMCO | S-methyl cysteine sulphoxide |
| u.v. | Ultra violet |

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The research programmes of all the agricultural research institutes supported from public funds are co-ordinated by the Agricultural and Food Research Council. The institutes publish annual or periodic reports on their research. Full details can be obtained from the secretaries of the institutes concerned.

## AFRC INSTITUTES

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| AFRC INSTITUTE FOR ANIMAL HEALTH | Compton, Near Newbury, Berkshire RG16 0NN |
| Compton Laboratory | Compton, Near Newbury, Berkshire RG16 0NN |
| Houghton Laboratory | Houghton, Huntingdon, Cambridgeshire PE17 2DA |
| Pirbright Laboratory | Ash Road, Pirbright, Woking, Surrey GU24 0NF |
| AFRC & MRC Neuropathogenesis Unit | Ogston Building, West Mains Road Edinburgh EH9 3JF |
| AFRC INSTITUTE OF ANIMAL PHYSIOLOGY AND GENETICS RESEARCH | Babraham Hall, Babraham, Cambridge CB2 4AT |
| Cambridge Research Station | Babraham, Cambridge CB2 4AT |
| Edinburgh Research Station | Roslin, Midlothian EH25 9PS |
| ARFRC INSTITUTE FOR GRASSLAND AND ANIMAL PRODUCTION | |
| Hurley Research Station | Hurley, Maidenhead, Berkshire SL6 4LR |
| North Wyke Research Station | Okehampton, Devon EX20 2SB |
| Roslin Research Station | Roslin, Midlothian EH25 9PS |
| Shinfield Research Station | Church Lane, Shinfield, Reading Berkshire RG2 9AQ |
| Welsh Plant Breeding Station | Plas Gogerddan, Aberystwyth, Dyfed SY23 3EB |
| AFRC INSTITUTE OF ENGINEERING RESEARCH | Wrest Park, Silsoe, Bedford MK45 4HS |
| AFRC INSTITUTE OF FOOD RESEARCH | Shinfield, Reading RG2 9AT |
| Bristol Laboratory | Langford, Bristol BS18 7DY |
| Norwich Laboratory | Colney Lane, Norwich NR4 7UA |
| Reading Laboratory | Shinfield, Reading RG2 9AT |

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|---|---|
| AFRC INSTITUTE OF ARABLE CROPS RESEARCH | Rothamsted Experimental Station<br>Harpenden, Herts AL5 2JQ |
| Long Ashton Research Station | Long Ashton, Bristol BS18 9AF |
| Rothamsted Experimental Station | Harpenden, Herts AL5 2JQ |
| Unit of Insect Neurophysiology and Pharmacology | Department of Zoology, University of Cambridge, Downing Street<br>Cambridge CB2 3EJ |
| Broom's Barn Experimental Station | Highham, Bury St. Edmunds, Suffolk<br>IP28 6NP |
| AFRC INSTITUTE OF HORTICULTURAL RESEARCH | Bradbourne House, East Malling<br>Maidstone, Kent ME19 6BJ |
| East Malling | East Malling, Maidstone, Kent<br>ME19 6BJ |
| Littlehampton | Worthing Road, Littlehampton<br>West Sussex BN17 6LP |
| Wellesbourne | Wellesbourne, Warwick CV35 9EF |
| Department of Hop Research | Wye College, Wye, Ashford, Kent<br>TN25 5AH |
| AFRC INSTITUTE OF PLANT SCIENCE RESEARCH | John Innes Institute, Colney Lane<br>Norwich NR4 7UH |
| Cambridge Laboratory | Maris Lane, Trumpington,<br>Cambridge CB2 2LQ |
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| Nitrogen Fixation Laboratory | University of Sussex, Brighton, Sussex<br>BN1 9RQ |
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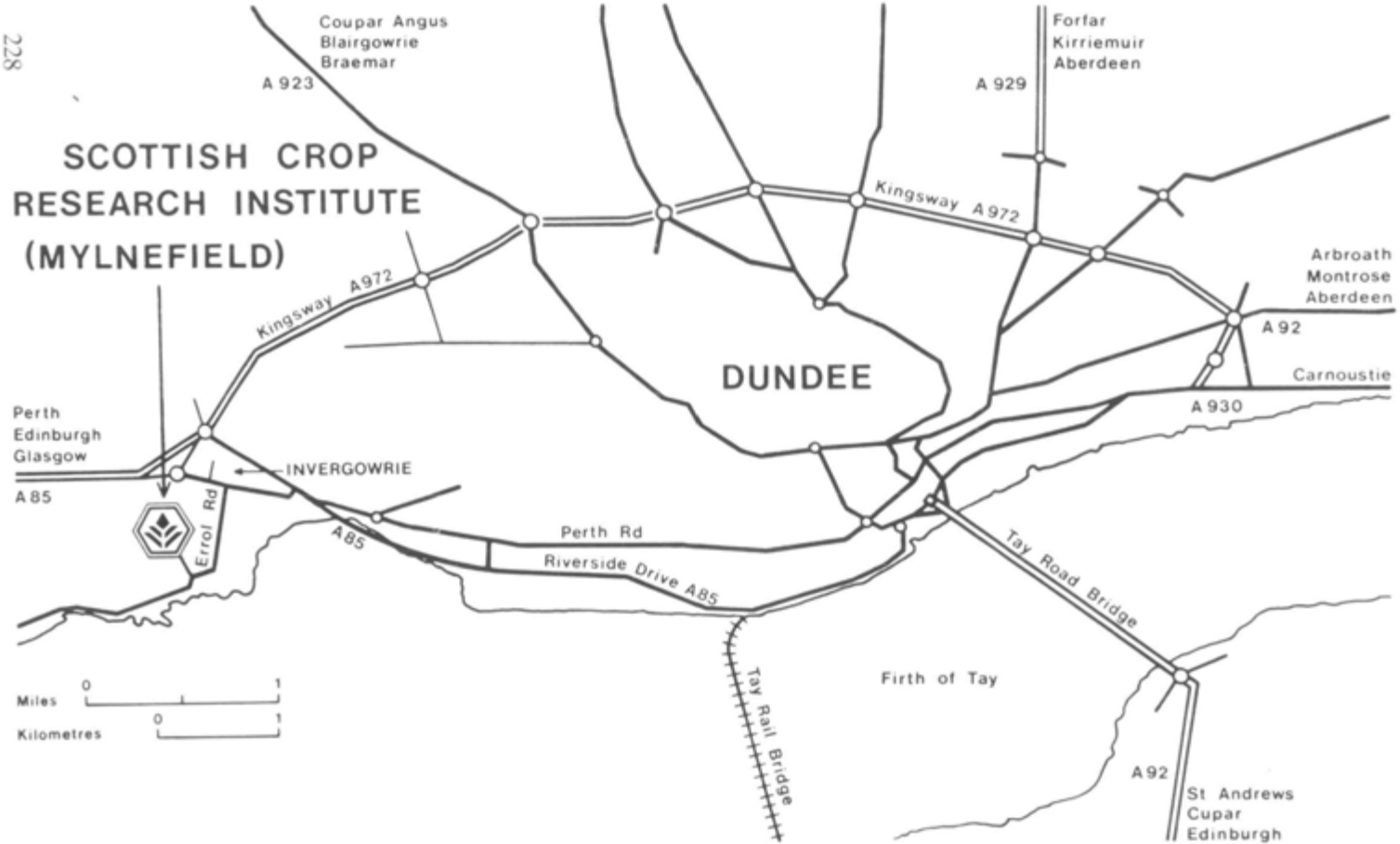
| HANNAH RESEARCH INSTITUTE | Ayr, Scotland KA6 5HL |
| MACAULAY LAND USE RESEARCH INSTITUTE | Craigiebuckler, Aberdeen AB9 2QJ |
| | Bush Estate, Penicuik, Midlothian<br>EH26 0PY |
| MOREDUN RESEARCH INSTITUTE | 408 Gilmerton Road, Edinburgh<br>EH17 7JH |
| ROWETT RESEARCH INSTITUTE | Greenburn Road, Bucksburn, Aberdeen<br>AB2 9SB |
| SCOTTISH CROP RESEARCH INSTITUTE | Invergowrie, Dundee DD2 5DA |
| SCOTTISH AGRICULTURAL STATISTICS SERVICE | University of Edinburgh, James Clerk Maxwell Building, King's Buildings<br>Mayfield Road, Edinburgh EH9 3JZ |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