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SCOTTISH CROP RESEARCH INSTITUTE

ANNUAL REPORT 1987

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(AS AT 31st DECEMBER 1987)

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R. A. Duff, B.Sc.	SO	Chemistry Department
A. Duncan, M.Sc.	SO	Brassica Breeding Department
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R. Forrest, B.Sc.	SO	Mycology and Bacteriology Department
Jennifer Gorrod	ASO	Physiology and Crop Production Department
Julie A. Graham, B.Sc.	SO	Soft Fruit Breeding Department
T. D. Heilbronn, M.Sc.	HSO	Physiology and Crop Production Department
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A. V. Wheelwright, B.Sc.	SO	SASS
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M. Young, H.N.D.	SO	Physiology and Crop Production Department

* Honorary Lecturer in the University of Dundee.
† Honorary Senior Lecturer in the University of St. Andrews.
\+ Honorary Lecturer in the University of St. Andrews.
‡ Visiting Professor in the University of Strathclyde.
° Honorary Professor in the University of St. Andrews.

GENERAL REPORT

J. R. HILLMAN

Continued appraisal of all aspects of agricultural research and development in the United Kingdom, coupled with the restructuring of institutes in the Agricultural and Food Research Service (AFRS) and the general climate of rigorously enforced financial controls, provided an interesting backdrop to the changes that took place at SCRI during 1987. The year was essentially one of substantial change and new challenges.

In April there were three important initiatives that extended the remit of the Institute. Firstly, the Scottish Agricultural Statistics Service (SASS) was established as a special unit under the administration of SCRI to provide an integrated statistical service for the five Scottish Agricultural Research Institutes (SARIs) and the three Scottish Agricultural Colleges (SAC). SASS is centred in the King's Buildings, University of Edinburgh, incorporating the staff formerly employed there by the Agricultural and Food Research Council (AFRC) Unit of Statistics in addition to groups of statisticians in Aberdeen, Ayr and Dundee. Under the leadership of the Director, R. A. Kempton, the Service rapidly demonstrated the value of a unified statistical consultancy network covering advice to scientists, new areas of application, modelling and training. Several organisations placed contracts with SASS in its first year of existence. The second initiative was the establishment of new multidisciplinary programmes on roots and soil microbiology. Thirteen staff members joined the Institute from the former Macaulay Institute for Soil Research at Aberdeen to work in these environmentally related programmes which involve five science departments. For the third initiative, the Departments of Cereal Breeding and Physiology and Crop Production embarked on a new programme on the physiology and genetics of arable legumes.

Further development of the scientific base of the Institute occurred towards the end of the year when the Tissue Culture and Cytology Unit at Pentlandfield was transferred to Mylnefield and substantially enlarged to form a separate Department headed by W. Powell within the Plant Breeding Division. This department has special responsibility to carry out investigations on gene transfer systems, restriction fragment length polymorphism, transposon tagging and the control of cellular differentiation, as well as devising systems for plant regeneration from cells and tissues.

The privatisation of the National Seed Development Organisation (NSDO), which marketed state-bred cultivars from institutes in the AFRS,

created a need for alternative marketing arrangements for potential cultivars and plant breeding material from SCRI. As a condition of sale to the private sector, all SCRI cultivars with National List / Plant Variety Rights status, or in the process of attaining such status at the time of the NSDO sale, were transferred to NSDO so that neither the Department of Agriculture and Fisheries for Scotland (DAFS) nor SCRI has access to revenue from these cultivars. Discussions about new marketing arrangements were held with DAFS and in response to a press release several companies submitted proposals for the commercial development of plant material derived from the SCRI breeding and genetics programmes. In the interim, SCRI, jointly with DAFS, continued to enter potential cultivars of its mandate crops for statutory testing.

A detailed analysis of scientific and administrative computing requirements in the SARIs and SAC was carried out by a sub-committee of the DAFS Joint Management Board (JMB), taking into account the close relationships that exist with the Edinburgh University Computing Service (EUCS) and the AFRC. Implementation of the main recommendation of the JMB to use EUCS for the support of computing services in the Scottish System will take place in the new year.

Development of the Mylnefield site was a feature of 1987. A two-storey modular laboratory and office block at the west end of the Virology/ Zoology wing of the main building was completed in March. By the end of the year on a site between the Hughes building and the boiler house a large laboratory and office block, containing a much-needed seminar room, awaited final commissioning checks prior to occupation in early 1988 by staff from the Departments of Cereal Breeding, Chemistry, Data Processing, Physiology and Crop Production, and Tissue Culture. Site levelling at the north-west part of the campus preceded the erection of four seedling houses which will eventually form part of the potato breeding and genetics glasshouse complex. Negotiations for the installation of additional glass-house and header-house facilities for the Mycology and Bacteriology Department were at an advanced stage, and detailed discussions were under way with DAFS on the final stage of the protracted transfer from Pentlandfield involving the construction for the Potato Breeding Department of the remainder of their glasshouse and header-house complex and a combined crop-handling, laboratory and office building on a site adjacent to the main car park.

Until a tract of land suitable for the cultivation of seed potatoes to the highest phytosanitary standards becomes available within relatively close proximity to Mylnefield, the Blythbank operations south of Edinburgh will be retained. Nevertheless, DAFS has been notified of our intention to withdraw completely from Pentlandfield and The Murrays farm in 1989, subject to satisfactory progress in the final phase of the amalgamation building programme. Bearing in mind the inconvenience of operating on

split sites, the use of temporary accommodation and the disruption caused by moving to new laboratories, the drawn-out amalgamation has not depressed scientific output as was feared when the fusion of the Scottish Horticultural Research Institute and the Scottish Plant Breeding Station to form SCRI began in 1981. I commend the staff for their patience, adaptability and co-operation, and DAFS for their vision and support despite restricted capital resources.

In March, B. D. Harrison was elected Fellow of the Royal Society in recognition of his major contributions to plant virus research. This prestigious award to the Head of the Virology Division signals the scientific strength of plant virology at SCRI and the pivotal role of Professor Harrison. Molecular biological and genetic engineering technologies are now employed in most of the research of the virologists, and are being rapidly incorporated into the other science departments.

Many of the problems afflicting agricultural research and development relate directly to the over-production of a relatively narrow range of agricultural commodities. This distortion of farming is caused by selective subsidies arising from the Common Agricultural Policy of the European Economic Community and it gives rise to disproportionately large political, economic and environmental impacts, no matter if the surpluses may in the fullness of time prove to be a transient feature of food production in the western world. Some aspects of applied research and development contribute to the enhancement of productivity and there is pressure from various sources for the direct beneficaries of this short-term work — the farmers, food processors and associated industries, the retail trade — to help finance it. Special mention must be made of those levy boards based on plant commodities, notably the Potato Marketing Board, the Home-Grown-Cereals Authority and the Horticultural Development Council. They have demonstrably recognised the value of, and need for, research and development by investing in selected programmes in the AFRC, the Agricultural Development and Advisory Services, SAC and SARI during difficult times for farming. Funding out of the public purse of long-term agricultural research at the basic and strategic levels is crucial for proper exploitation of modern physical, chemical and, in particular, biological technologies that can now revolutionise the genetic relationships between organisms, their responses to and effects on the environment, and their structure and biochemistry. We are at the threshold of redesigning plants and microorganisms in the service of mankind.

The Priorities Board for Research and Development in Agriculture and Food has a remit covering the whole of the publicly funded agricultural and food research and development activity sponsored by DAFS, the Ministry of Agriculture, Fisheries and Food, the Department of Agriculture in Northern Ireland, and the AFRC. Its terms of reference are to advise the UK Agriculture Ministers and the Chairman of the AFRC on priorities for

the allocation of their research and development budgets. In June, the second Priorities Board report was released giving recommendations for budget allocations that lend support for the changes introduced to the SCRI research programmes.

The late Professor John L. Jinks was an eminent scientist who as Professor of Genetics at Birmingham University published numerous influential papers on biometrical genetics and supervised a stream of post-graduate research students, some of whom were appointed to SCRI. As Secretary of the AFRC, he was an outstanding leader in extremely difficult times. Even when he was very ill he introduced major changes to the direction of the AFRC, responding in a constructive way to the harsh financial climate in which agriculture and many areas of science have to survive and flourish. His untimely death in 1987 was deeply felt by his many friends at SCRI. The announcement in December that Professor W. D. P. Stewart would be appointed on 1 January 1988 as a successor to Professor Jinks was welcomed by the scientific community and especially by SCRI. Professor Stewart, the Boyd Baxter Professor of Biology in the University of Dundee, is a member of our Governing Body. He is a prominent scientist with all the necessary attributes to ensure the successful evolution of the AFRC in fostering basic research in the life sciences and related environmental sciences.

Members of staff were saddened by the death in January of Peter R. Massalski, a respected young colleague and friend who, in his three years at SCRI, had made an increasing impact on research which used monoclonal antibodies to investigate problems in plant virology. His lively personality and unfailing helpfulness will be missed by many but the progress he made will be of great value to his successors.

The Institute depends upon the help and co-operation of others, either individuals or organisations, without whose assistance the work would be greatly handicapped. The assistance takes the form of the 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 its collaborators and very appreciative of the help that they give.

External finance

Agricultural Genetics Company	£31,648
Anglia Canners	£250
BASF United Kingdom Ltd	£400
Beecham Foods	£5,225
British Council	£500
British Crop Protection Council	£2,387

British Technology Group	£1,755
CIP	£8,664
L. Clause	£735
Corse of Kinnoir Ltd	£1,129
DAFS Scientific Services	£1,140
Dalgety Agriculture Ltd	£1,380
European Plant Protection Organisation	£500
Farm Protection Ltd	£400
Germicopa Récherché	£736
Hillsdown Holdings	£500
Home Grown Cereals Authority	£8,288
Horticultural Development Council	£12,450
Imperial Chemical Industries	£400
Israel Department of Agriculture	£570
Oak Park Research Institute	£643
Overseas Development Administration	£46,114
Potato Marketing Board	£10,228
James Robertson & Sons	£200
Schering Agriculture	£400
Scottish Agricultural Industries plc	£300
Scottish Development Agency	£11,500
Shell Chemicals UK Ltd	£2,000
Sumitomo Chemical Company	£2,875
University of Kiel	£100
Walker's Crisps Ltd	£2,440
SASS Consultancies and miscellaneous income	£50,268

Permanent Appointments and Internal Transfers

B. Alexander	ASO	Physiology and Crop Production Department
E. Baird	ASO	Transferred to Tissue Culture Department
I. Black[1]	SO	Data Processing Department
S. Buchan[1]	SO	Physiology and Crop Production Department
S. R. Clark	ASO	Data Processing Department
J. Davidson	Typist	Administration Division
D. C. Gordon[1]	HSO	Physiology and Crop Production Department
B. S. Griffiths[1]	HSO	Zoology Department
D. J. Lineham[1]	UG7	Physiology and Crop Production Department
J. Lyon	EWII	Cereal Breeding Department
G. L. Malloch	ASO	Zoology Department
A. L. March	ASO	Tissue Culture Department
W. Matheson[1]	HSO	Chemistry Department
J. W. McNicol	UG7	Transferred to SASS

[1]Transferred from Macaulay Land Use Research Institute

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S. D. Porter	SO	Cereal Breeding Department
E. A. Rees	SO	Mycology and Bacteriology Department
K. Ritz[1]	HSO	Mycology and Bacteriology Department
G. W. Robertson[1]	SSO	Chemistry Department
D. Robinson[1]	HSO	Physiology and Crop Production Department
A. M. Smith	ASO	Mycology and Bacteriology Department
W. M. Stein[1]	HSO	Chemistry Department
F. E. C. Stewart	ASO	Zoology Department
K. D. Webster	ASO	Mycology and Bacteriology Department
R. E. Wheatley[1]	HSO	Mycology and Bacteriology Department
C. J. Wilkinson[1]	ASO	Physiology and Crop Production Department
A. J. Wilshin	ASO	Soft Fruit Breeding Department
K. H. M. Young	ASO	Soft Fruit Breeding Department

Awards

E. Baird	Cereal Crop Inspectors Licence
J. T. Bennett	ATB Certificate of Craftsmanship. Scottish Association of Young Farmers' Clubs, Certificate of Proficiency: safe operation and maintenance, fork lift truck
E. M. Burnett	Roy Waterson Memorial Trust Award and James E. Rennie PMB Award
W. Craig	SCOTVEC Ordinary National Certificate in Biology
Y. Downie	SCOTVEC Higher National Certificate in Biology
T. D. Heilbronn	M.Sc., University of Dundee
S. K. M. H. Hemida	Ph.D., University of Dundee
W. W. Kirk	Ph.D., University of Dundee
G. Menzies	SCOTVEC Ordinary National Certificate in Photography/Audio Visual
S. E. Miller	SCOTVEC Ordinary National Certificate in Biology
L. S. Monk	Ph.D., University of St. Andrews
A. F. Murant	Fellow of the Institute of Biology Honorary Lectureship, University of Dundee
A. Nicoll	ATB Certificate of Craftsmanship. Scottish Association of Young Farmers' Clubs, Certificate of Proficiency: safe operation and maintenance, fork lift truck
G. G. Pollock	ATB Certificate of Craftsmanship. Scottish Association of Young Farmers' Clubs, Certificate of Proficiency: fertiliser distribution.
A. M. Smith	SCOTVEC Ordinary National Certificate in Biology
C. A. Stewart	M.Sc., University of Glasgow
J. S. Swanston	Membership of the Institute of Biology

[1]Transferred from Macaulay Land Use Research Institute

A. J. Wilshin	SCOTVEC Higher National Diploma in Biology
K. M. Wright	Ph.D., University of Newcastle
P. W. Yeaman	ATB Certificate of Craftsmanship.
	Scottish Association of Young Farmers' Clubs, Certificate of Proficiency: safe operation and maintenance, fork lift truck

Promotions

A. Booth	ASO	Cereal Breeding Department
J. E. Bradshaw	UG7	Brassica Breeding Department
S. M. S. Dawson	SO	Virology Department
R. P. Ellis	UG7	Cereal Breeding Department
C. A. Glasbey	UG7	Scottish Agricultural Statistics Service
J. R. T. Hodgkin	UG7	Brassica Breeding Department
R. A. Jefferies	HSO	Physiology and Crop Production Department
R. P. Keith	ASO	Cereal Breeding Department
D. K. L. MacKerron	UG7	Physiology and Crop Production Department
B. Marshall	UG7	Physiology and Crop Production Department
W. Powell	UG7	Tissue Culture Department
D. A. M. Prior	SO	Physiology and Crop Production Department
G. R. Young	SO	Cereal Breeding Department

Resignations

L. F. Ainsworth	Zoology Department
E. L. Allsworth	Estate Division
A. Biran	Cereal Breeding Department
E. M. Borrino	Tissue Culture Department
K. A. Currie	Administration Division
E. A. Davidson	Estate Division
B. R. Hainsworth	Cereal Breeding Department
J. A. L. Joyce	Potato Breeding Department
I. J. Kinnaird	Physiology and Crop Production Department
A. Kumar	Brassica Breeding Department
J. Mellon	Engineering and Maintenance Division
E. H. Patterson	Administration
L. M. Pitcher	Soft Fruit Breeding Department
A. Purves	Estate Division
J. D. Watson	Data Processing Department
R. Waugh	Virology Department

Termination of Short-term Appointment

E. W. Vandome	Information Services Division

Redundancies. Voluntary, Premature and Flexible Retirements

M. Armstrong	Tissue Culture Department
P. E. Dyce	Mycology and Bacteriology Department
V. Goodall	Tissue Culture Department
W. I. S. Harrower	Engineering and Maintenance Division
E. B. Hoy	Chemistry Department
H. B. Jamieson	Estate Division
K. A. Liddell	Tissue Culture Department
C. E. Lyon	Zoology Department
K. Petrie	Estate Division
J. Tulloch	Estate Division
M. A. Tunnock	Estate Division

Retirements of Permanent Staff

M. M. Anderson, UG7, Soft Fruit Breeding Department, retired on 6 June after 34 years' service.

I. A. McLeish, AO, Administration Division, retired on 21 April after 21 years' service.

M. I. McMaster, GOIV, Information Services Division, retired on 15 May after 21 years' service.

G. Merchant, Craftsman, Engineering and Maintenance Division, retired on 30 April after 24 years' service.

R. D. Taylor, P & GSD, Estate Division, retired on 17 July after 35 years' service.

P. B. Topham, UG7, retired as Head of the Data Processing Department on 6 September after 25 years' service.

Visiting Workers

R. Alonso (National Institute of Agricultural Research, Madrid, Spain) spent 4 months at the SASS centre working on methods for analysis of coordinated variety trials (SASS Edinburgh).

G. R. Brown (University of Kentucky) arrived in May to work for 3 months studying water relations and learning Scottish cultural practices of the raspberry (Physiology and Crop Production Department).

A. Burns (Wolverhampton Polytechnic) spent 6 weeks investigating pulsed-field gel electrophoresis (Brassica Breeding and Chemistry Departments).

M. Claeys (University of Ghent, Belgium) spent 1 week in April learning methods for processing nematodes for study with the transmission electron microscope (Zoology Department).

C. Greif (IBMC, Strasbourg, France) spent 4 weeks in September learning methods for studying virus infection of protoplasts, supported by the Federation of European Biochemical Societies (Virology Department).

E. de Jongh (Nematology Department, Agricultural University, Wageningen, The Netherlands) spent June to August investigating host finding behaviour and invasion in potato cyst nematodes (Zoology Department).

W. G. Henry (St. Helena) spent 2 months learning techniques for work on potato late blight and also all aspects of potato breeding, particularly trialling and roguing (Mycology and Bacteriology and Potato Breeding Departments).

W. Iritani (Washington State University) spent 4 months studying the physiological disorder, brown centre, in potato (Physiology and Crop Production Department).

T. Kühne (Institut für Phytopathologie, Aschersleben, East Germany) spent 2 weeks in November discussing virus research in progress and modern methods of virus detection (Virology Department).

Christa Lankes (University of Bonn, West Germany) spent 2 months in February-April learning techniques for detecting viruses in soft fruit plants, funded by the British Council (Virology Department).

F. J. Legorburu (Potato Improvement Station, Vitoria, Spain) spent 4 months from April-July studying nucleic acid hybridisation methods for virus detection (Virology Department).

A. Nachmias (Gilat Experimental Station, Israel) spent 1 week planning joint projects on potato diseases caused by Erwinias in Israel and Scotland (Mycology and Bacteriology Department).

L. T. Peiris (Rubber Research Institute, Sri Lanka) spent 3 weeks at the SASS centre learning methods for statistical analysis in agriculture (SASS Edinburgh).

T. S. Peiris (Coconut Research Institute, Sri Lanka) spent 2 weeks at the SASS centre learning methods for statistical analysis (SASS Edinburgh).

J. Penarande Valverde (University of Bogota, Colombia) began a sabbatical year studying the replication of potato leafroll virus in protoplasts (Virology Department).

M. Pinhonen (Department of Genetics, University of Uppsala, Sweden) spent 1 week learning techniques for testing pathogenicity of *Erwinia carotovora* (Mycology and Bacteriology Department).

E. Tytler (Department of Bioscience and Biotechnology, University of Strathclyde) spent 1 week working on the electron microscopy of membranes enclosing starch granules in wheat (Zoology Department).

U. Wyss (Institute for Plant Pathology, University of Kiel, West Germany) spent 1 week in March analysing electron micrographs (Zoology Department).

A. L. Zepp (Research Institute of Pomology and Floriculture, Brzezna, Poland) spent June and July studying lectin binding and host-finding in *Pratylenchus* spp (Zoology Department).

Research Students

O. Acosta (Post-graduate student funded by ICETEX, Colombia) continued studies on the replication of raspberry ringspot virus in protoplasts (Virology Department).

P. J. Burgess (SERC-RCCA post-graduate student, jointly with Queen's University, Belfast) continued studies on the ecology of soft rot erwinias on the potato phylloplane (Mycology and Bacteriology Department).

K. Chalmers (SERC) began studies on the molecular genetics of barley (Tissue Culture Department).

S. C. Dharmaratne (Post-graduate student, Rubber Research Institute, Sri Lanka, funded by the World Bank) continued studies on incompatibility in *Brassica napus* (Brassica Breeding Department).

S. Finney (SERC) began studies on haploid production systems in barley (Tissue Culture Department).

S. K. M. A. Hemida (Post-graduate student funded by University of Assiut, Egypt) completed studies on the properties of parsnip yellow fleck and anthriscus yellows viruses (Virology Department).

L. V. Lopez Llorca (Post-graduate student funded by the British Council) continued 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) began research on chemo- and electrotactic localisation of plant roots by parasitic nematodes and fungi (Zoology Department).

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

A. T. Ploeg (Agricultural University, Wageningen, The Netherlands/ British Council) commenced 1 year investigating the transmission of tobraviruses by trichodorid nematodes (Zoology Department).

L. D. Ramsay (SERC-RCCA post-graduate student, jointly with University of Birmingham) began studies on applications of biometrical genetics to swede breeding (Brassica Breeding Department).

N. T. Smoktunowicz (PMB, post-graduate student) continued studies on the influence of nitrogen on assimilate partitioning in the potato plant (Physiology and Crop Production Department).

W. Stone (SERC-RCCA post-graduate student, jointly with University of Birmingham) continued studies on frost tolerance and plant habit in the black currant (Soft Fruit Breeding Department).

I. Toth (SERC-RCCA post-graduate student, jointly with University of Warwick) commenced studies on genetic analysis of pathogenicity of *Erwinia carotovora* (Mycology and Bacteriology Department).

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).

V. Caine (University St. Andrews) worked for 8 weeks analysing the relationships between weather parameters and yield of black currant (Data Processing Department).

J-P. Camm (HGCA funded). Three year study of milling energy and barley malting quality (Cereal Breeding Department).

P. Cochrane (IFS, jointly with Edinburgh University School of Agriculture). Three year study of the biochemical characteristics of good crisping quality in *Solanum tuberosum*. (Chemistry, Potato Breeding, and Physiology and Crop Production Departments).

S. Cooper-Bland (IFS). Three year study of somatic hybridisation in potato (Tissue Culture Department).

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

R. A. Duff (Beechams Ltd). Six month study on metabolic profiling in relation to gall mite resistance in black currant (Soft Fruit Breeding and Chemistry Departments).

A. Duncan (IFS, jointly with MLURI). Three year study of glucosinolates in forage brassicas, their influence on feeding quality, and implications for plant breeding (Brassica Breeding Department).

N. S. Duncan (HGCA funded) completed a 6 month project to extract and identify weed seeds and free-living nematodes from soils collected from 100 cereal fields throughout Scotland (Physiology and Crop Production Department).

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

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

J. Gorrod (BTG funded). Four month study of the nematicide potential of natural plant products (Zoology Department).

J. Gorrod (HGCA funded). Three year study on the effects of weed control strategies in cereals on the weed seedbank of arable soils (Physiology and Crop Production Department).

J. A. Graham (IFS). Three year study on use of *Agrobacterium* species as vectors of DNA (Soft Fruit Breeding Department).

T. D. Heilbronn (PMB funded). Two year project, extendable to 3 years, on forecasting the yield of the national potato crop from weather and soil data and agronomic practice (Physiology and Crop Production Department).

A. Kumar (IFS). Three year study of novel selection methods for characters of agronomic importance in forage brassicas (Brassica Breeding Department).

I. K. Kumar and R. Rajeshwari (ODA funded). Three year and one year studies respectively of virus components involved in groundnut rosette disease (Virology Department).

P. G. Lanham (IFS). Three year study of molecular genetics of the synthesis, export and secretion of the pectic enzymes of *Erwinia carotovora* as affected by temperature (Mycology and Bacteriology Department).

F. H. Lowe (HGCA funded). Six month study on early generation assessment of malting quality in barley (Cereal Breeding Department).

A. Monaghan (HDC funded) completed a 5 month assignment to assist with the evaluation of alternative methods of cane vigour control in raspberries (Physiology and Crop Production Department).

L. S. Monk (IFS). Three year study on calcium-related disorders of potato tubers (Physiology and Crop Production Department).

A. N. Morrice (IFS). Three year study of novel selection methods for characters of agronomic importance in forage brassicas (Brassica Breeding Department).

E. A. Murant and R. Waugh (AGC funded). Three year study of genetic engineering of virus resistance (Virology Department).

J. Robb (IFS). Three year study on the nature and function of nematode feeding tubes (Zoology Department).

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

D. Stewart (IFS). Three year immunological study of resistance to potato cyst nematodes (Zoology Department).

W. T. G. van de Ven (Agricultural University, Wageningen, The Netherlands). Five months working on aspects of 'run off' and fertility in black currant (Soft Fruit Breeding Department).

W. T. G. van de Ven (Agricultural University, Wageningen, The Netherlands). Ten weeks studying the infection of raspberry canes by *Elsinoe veneta* (Mycology and Bacteriology Department).

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

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

A. V. Wheelwright (HDC funded). Two year post as consultant statistician for DAFS ASS, East Craigs (SASS centre, Edinburgh).

S. C. K. Williams (HDC funded). Two year study of *in vitro* methods of chromosome doubling in *Rubus* (Soft Fruit Breeding Department).

G. W. Wilson (IFS). Three year barley modelling project (jointly with ESCA) (Cereal Breeding Department).

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

M. Young (BCPC funded). Completed a 12 month project to expand and update the Herbrex data-base and to produce Potato and Barley bulletins therefrom (Physiology and Crop Production Department).

M. Young (Walker's Crisps Ltd). One year study of the reasons for quality variation in Record potatoes grown for crisping (Physiology and Crop Production Department).

Sandwich Course Students

N. Armitage (North East London Polytechnic) worked on virus resistance screening (Potato Breeding Department).

Catriona M. Buchanan (Napier College of Technology) assisted with coordinated trials (SASS Edinburgh).

S. Burgers (Agricultural University, Wageningen) worked for 5 months on biometrical genetical aspects of swede breeding (Brassica Breeding Department).

G. Collins (Coventry Polytechnic) assisted scientific staff at the Rowett Research Institute (SASS Aberdeen).

Lysbeth Hof (Agricultural University, Wageningen, The Netherlands) worked on the resistance of raspberries to infection by *Elsinoe veneta* (Mycology and Bacteriology Department and Soft Fruit Breeding Departments).

M. Krysse (Agricultural University, Wageningen, The Netherlands) spent 14 weeks working on water relations of the potato and of the raspberry (Physiology and Crop Production Department).

P. S. Leighton (Manpower Services Commission) Database development work (Data Processing Department).

Susan E. Leonard (University of Bath) assisted with coordinated trials (SASS Edinburgh).

Christa Wieland (University of Hohenheim, West Germany) spent 5 weeks studying aspects of barley breeding (Cereal Breeding Department).

Visits Abroad

A. N. E. Birch and J. A. T. Woodford visited the Department of Entomology, University of Wageningen, The Netherlands from August 23-29 to attend the Electrical Penetration Graph Summer School where they participated in monitoring aphid feeding using a specially designed amplifier.

D. J. F. Brown visited the Institute for Wine-making and Viticulture, Neustadt, West Germany from May 9-16 to discuss specificity of virus transmission by nematodes and to organise collaborative research. He also paid a short visit to Ghent University, Belgium and to EEC Headquarters, Brussels to discuss a collaborative project on transmission of tobraviruses by trichodorid nematodes.

J. Brown visited Israel, 14-24 June and Burgos, Spain, 19-24 September to assess SCRI potato clones in trials.

E. M. Burnett visited the Department of Plant Pathology, University of Wisconsin, USA, 21 September-19 October to become familiar with potato resistance testing techniques and seed production methods in Wisconsin.

I. R. Craigie visited Pavia, Italy from 14-18 September to attend the International Genstat Conference.

M. F. B. Dale visited Cyprus, 4-9 May to assess SCRI potato clones in trials.

H. V. Davies visited Washington State University from 3-7 August for discussions with potato physiologists and visit to seed and ware growing areas.

M. J. De, Maine visited Valencia, Spain, 16-21 May to assess SCRI potato clones in trials.

J. M. Duncan visited Aalborg, Denmark, 26-31 July, to attend the European Association of Potato Research Triennial Conference.

J. M. S. Forrest visited the Institute for Nematology in Munster and the University of Kiel, West Germany on 23-24 July for discussions on nematode feeding behaviour in relation to plant resistance.

R. Forrest visited the Complex Carbohydrate Research Center, Athens, Georgia, USA, 10-12 June, to discuss role of biologically active oligosaccharides from plant cell walls.

B. S. Griffiths attended an international symposium from 9-12 June on Ecology of Arable Land — the role of organisms in nitrogen cycling perspectives and challenges, at the Swedish University of Agricultural Sciences, Uppsala.

B. D. Harrison made an invited visit to the ORSTOM Centre d'Adiopodoume, Ivory Coast on 9-14 May to discuss research on whitefly-transmitted geminiviruses. On 14-19 September he made invited visits to centres of virus research in Finland and gave two medal lectures in Helsinki University. He visited and gave lectures at several plant virus laboratories in India on 17 October-3 November, funded by the British Council.

L. J. Hyman visited IPO, Wageningen, The Netherlands during 15-20 November to become familiar with serological methods of detecting erwinias on potatoes.

N. L. Innes attended Governing Board meetings of the ICRISAT in Hyderabad, India from 25-29 March and in Niamey, Niger and Kano, Nigeria from 8-14 September. In June he participated in a one-day meeting in Amsterdam, The Netherlands sponsored by the Winrock International Institute, USA, to discuss international vegetable research and development.

R. A. Kempton spent 7-19 August in Denmark visiting agricultural research institutes at the invitation of the Danish Agricultural Research Council. He contributed to a workshop on design and analysis of field trials at the Royal Agricultural and Veterinary University, Copenhagen and gave a paper at a Biometric Society symposium at Foulum Research Centre in Jutland. He also visited the National Institute of Agricultural Research, Madrid, Spain from 3-8 July to discuss future collaboration.

D. M. Kennedy visited various research centres in British Columbia, Canada, Washington D.C., and New York State, USA, 24 April-20 May where *Phytophthora* root rot of raspberries is studied and to make isolations of the pathogen.

G. R. Mackay visited Valencia, Spain, 16-21 May, Negev, Israel, 14-24 January and (financed by the SSPDC) Vila Real, Portugal, 10-13 September to assess SCRI potato clones in trials.

D. K. L. MacKerron attended an International Workshop on Recent and Future Developments of the Potato in the World organised by the ISHS at Wageningen, The Netherlands on 7-8 April.

J. W. McNicol visited Brussels, Belgium, 3-4 December to attend an EC Coordination meeting for agricultural research — NIR ring test on grass silages.

B. Marshall visited Wageningen, The Netherlands, on 20-24 July to attend a meeting of the EC Joint Field Bean Trials (Northern Group) to draft proposals for a new series of experiments on nutritional quality and simulation studies. He also visited CABO, SVP and departments of the Agricultural University, Wageningen, The Netherlands, on 23-27 November, supported by an EC exchange-of-scientist grant, to initiate collaborative work in physiology.

M. A. Mayo discussed recent research results with virologists at the Agriculture Canada Research Station, Vancouver on 5 August and attended the International Congress of Virology, Edmonton on 8-15 August.

A. F. Murant spent 11-13 March examining virus diseases in groundnut crops in Central and Southern Malawi while on an invited visit.

A. C. Newton, visited Risø, Roskilde, and University of Copenhagen, Denmark, and IPO and the Agricultural University, Wageningen, The Netherlands, 24-31 August to discuss common interests and possible collaboration on cereal mildew and other diseases.

M. C. M. Pérombelon, Department of Plant Pathology, University of Wisconsin, USA 2-9 March; CIP and San Ramon, Peru 10-15 March to discuss aspects of research on erwinias. He visited Israel, 30 March-5 April at the invitation of the Vegetable Marketing Board to discuss the potato blackleg problem. He also visited the Station de Pathologie Vegetale, INRA, Versailles, France, 23-28 November to discuss serological methods of detection of erwinias.

M. S. Phillips and D. L. Trudgill visited the International Agricultural Centre, Wageningen, The Netherlands between 24-26 November to respectively contribute to and act as Chairman of an *ad hoc* EPPO panel on methods of assessing resistance to and pathotypes of potato cyst nematodes.

I. M. Roberts attended by invitation the opening of the Philips Electron Optical Factory, Eindhoven, The Netherlands on 14-15 September. From 1-31 October he served as consultant on electron microscopy to FAO, for a visit to the Indian Agricultural Research Institute, New Delhi.

W. M. Robertson visited the University of Kiel (West Germany) on 23-27 July for joint discussions on the role of lectins and carbohydrates in recognition systems within nematodes. He also visited the Volcani Center, Bet Dagan, Israel from 20 October-4 November to extend these discussions and organise joint research.

D. J. Robinson made invited visits to ICRISAT, Hyderabad and IARI, New Delhi from 10-20 January and gave talks at both on complementary DNA techniques for virus detection.

H. E. Stewart visited Israel from 24-31 May to observe *Alternaria* and other foliage diseases in the potato trials at Gilat Regional Experiment Station.

J. S. Swanston visited barley breeding and research institutes in Scandanavia from 8-12 June to study work related to the quality of barley grain and malt and its assessment in breeding programmes.

D. L. Trudgill spent 26 August-4 September in Finland visiting the laboratories of the Plant Quarantine Service and the Agricultural Research Centre at Jokioinen to complete a programme of joint research on the northern root-knot nematode.

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

5 February	Scottish Seed Producers Group, University of St. Andrews	
	D. K. L. MacKerron	The importance of irrigation in the potato crop
26 February	ADAS Plant Pathologists Conference, Harrogate	
	J. M. Duncan (D. M. Kennedy)	*Phytophthora* root diseases of soft fruit
8-10 March	Consultative Group on Groundnut Rosette Disease, Lilongwe, Malawi	
	A. F. Murant (R. Rajeshwari)	Current research on groundnut rosette virus disease at the Scottish Crop Research Institute
15-17 March	Crop Protection in Northern Britain 1987, University of Dundee	
	A. N. E. Birch	Initial studies of swede resistance to turnip root fly in Scotland
	B. Boag	Nematode problems associated with fodder brassicas in Scotland
	S. C. Gordon (J. A. T. Woodford)	The biology of the clay-coloured weevil *(Otiorhynchus singularis)* in raspberries in eastern Scotland

	H. M. Lawson (J. S. Wiseman)	Preliminary evaluation of the tolerance of seed potato to isoxaben
	H. M. Lawson (J. S. Wiseman)	Evaluation of crop tolerance to napropamide applied as a late winter treatment in strawberry and raspberry plantations
	A. M. Spaull[1] (D. L. Trudgill) (M. S. Phillips)	Behaviour of three new potato clones in integrated control of potato cyst nematodes, *Globodera* species
	J. A. T. Woodford (S. C. Gordon) (G. N. Foster[2])	Recent observations on the spread and control of potato leaf roll virus in Scotland
16-20 March	Conference on Bacterial Diseases of Potato, CIP, Peru	
	M. C. M. Pérombelon	Ecology of the Erwinias causing stem and tuber rots
18 March	Edinburgh Plant Biology Forum, Genetic Manipulation of Plants, SCRI	
	J. R. T. Hodgkin	Gametophytic selection in brassicas
	R. J. McNicol	The use of *Agrobacterium* species for DNA introduction in *Rubus*
18 March	RMS, London	
	I. M. Roberts	Negative staining of virus particles
25 March	SCRI/PMB Conference — Towards Improved Seed Potato Production, Dundee	
	D. K. L. MacKerron	Irrigation requirements
	B. Marshall	Plant population considerations
	T. D. Heilbronn	Estimating production
30 March-3 April	Society for Experimental Biology Conference, University of York	
	H. V. Davies (H. A. Ross)	Genotypic variation in susceptibility of potato tubers to calcium-related physiological disorders
31 March-2 April	Ciba Foundation Symposium on Plant Resistance to Viruses, London	
	B. D. Harrison	Introduction

[1]Crop Protection Division, Edinburgh School of Agriculture
[2]Biological Science Division, WSAC

7-10 April	SGM, St. Andrews	
	B. D. Harrison	Plant virus transmission by vectors: mechanisms and consequences
	D. J. Robinson	Conservation and variation in plant virus genome nucleic acids
9-11 April	WMO Symposium on the Agrometeorology of the Potato, JAC, Wageningen, The Netherlands	
	D. K. L. MacKerron	A weather-driven model of potential yield in potato and its comparison with achieved yields.
4-8 May	International Seminar on African Cassava Mosaic Disease and its Control, Yamoussoukro, Ivory Coast	
	B. D. Harrison	African cassava mosaic geminivirus: properties and geographical variation
	D. L. Jennings	Host virus relationships of resistant cassava and ACMV and some implications for breeding and disease control
11-14 May	GCIRC 7th International Rapeseed Conference, Poznan, Poland	
	A. B. Wills (J. R. T. Hodgkin)	Pollen selection in *Brassica* species
10-12 June	International Union for the Protection of New Varieties of Plants — Technical Working Party on Automation and Computer Programs, Copenhagen, Denmark	
	M. Talbot	Testing of homogeneity on cross-fertilized plants; Guidelines for production of computer programs which can be readily assimilated into other plant variety computer systems
18-19 June	Coordination of R & D in potato physiology in the UK, University of St. Andrews	
	D. K. L. MacKerron	Overview of gross effects and mechanisms influencing yield
	B. Marshall	Overview of gross effects and mechanisms influencing tuber sizes

24-25 June	ADAS/SCRI Potato Workshop, Terrington St. Clement	
	P. D. Waister	How do we interpret experiments?
	(D. Rogers-Lewis[1])	
	D. K. L. MacKerron	Effects of water on potatoes
	(R. Bailey[2])	
	H. V. Davies	Effects of nitrogen on potatoes
	B. Marshall	ADAS/SCRI Seed rate programme
	(C. Speller[3])	
7-8 July	Martin Beale Memorial Symposium, London	
	C. A. Glasbey	New regression estimators resilient to potentially influential observations
12-17 July	First International Committee for Near Infra-red Spectroscopy Conference, Norwich	
	(D. R. Wilkin[4])	Detection of infestation in stored
	I. A. Cowe	products using NIR
	I. A. Cowe	Spectral reconstruction and self
	(J. W. McNicol)	improving calibration models
	(D. C. Cuthbertson)	through principal component analysis of NIR spectra
24 July-1 August	XIV International Botanical Congress, Berlin, West Germany	
	K. J. Oparka	Phloem unloading in the potato
	(D. A. M. Prior)	tuber
26-31 July	10th Triennial Conference of the European Association for Potato Research, Aalborg, Denmark	
	J. M. S. Forrest	Studies of the nature of host
	(W. M. Robertson)	finding by the potato cyst
	(Y. Spiegel[5])	nematode *Globodera rostochiensis*
	D. L. Trudgill	Clone by *Globodera pallida*
	(M. S. Phillips)	population interactions in
	(H. J. Rumpenhorst[6])	partially resistant potato genotypes
	P. D. Waister	Growth per stem and its influence
	(P. A. Gill)	on the numbers of tubers produced
	D. K. L. MacKerron	The susceptibility of the potato
	(R. A. Jefferies)	plant to waterlogging in the early growing season

[1]ADAS, Terrington EHF
[2]ADAS, Gleadthorpe EHS
[3]ADAS, Leeds
[4]MAFF, Slough
[5]Volcani Center, Bet Dagan, Israel
[6]Institut für Nematologie, Munster, West Germany

	R. L. Wastie (G. R. Mackay)	Testing clones for resistance to tuber soft rot *Erwinia carotovora* ssp. *atroseptica* by vacuum infiltration
	R. L. Wastie (P. D. S. Caligari) (H. E. Stewart)	Relationship between resistance and tolerance to late blight
8-15 August	7th International Congress of Virology, Edmonton, Canada	
	B. D. Harrison (M. A. Mayo) (D. J. Robinson) (D. C. Baulcombe[1])	Repressed virus replication and symptom expression in plants transformed with virus satellite nucleic acid
	A. F. Murant (S. K. M. A. Hemida[2]) (M. A. Mayo)	Plant viruses that resemble picornaviruses
22-27 August	Association of Applied Biologists meeting on viruses with fungal vectors, St. Andrews	
	H. Barker	Multiplication of potato leafroll virus in non-phloem tissue of *Nicotiana clevelandii*
	B. D. Harrison (M-J Farmer) (P. R. Massalski)	Properties of monoclonal antibodies to potato virus V
	M. A. Mayo (A. T. Jones) (M. J. Mitchell)	Possible aetiology of June yellows of strawberry
	I. M. Roberts	Electron microscope studies of the structure of the particles of tobacco ringspot virus
	D. J. Robinson	Relationships between furoviruses as judged by cDNA-RNA hybridisation and by serology
	R. M. Solomon (R. L. Wastie)	Management of PMTV and its vector by breeding and selection
7-8 September	AFRC meeting on Plant and Soil Nitrogen Metabolism, University of Sussex	
	H. V. Davies (H. A. Ross)	Nitrogen nutrition and nitrate reductase activity in *Solanum tuberosum*

[1]IPSR (Cambridge Laboratory)
[2]Research Student

7-9 September	AAB Residential Meeting, University of Reading Changing priorities in Crop Production and Food Processing	
	M. R. Cormack (R. M. Brennan)	Prospects for new soft fruit crops in the UK
17-20 September	Fallen Leaf Lake Conference California, USA, on the genus *Erwinia*	
	M. C. M. Pérombelon	New perspectives on the ecology of the soft rot erwinias in Scotland and Israel
3-10 October	XI International Congress for Plant Protection, Manila, Philippines	
	A. T. Jones	Vector resistance as a means of virus control: a review of achievements, prospects and problems
19-21 October	European Weed Research Society Workshop: Methodology and Models in Weed Science, IAC, Wageningen, The Netherlands	
	H. M. Lawson	The use of weed seedbank data in the selection of herbicide recommendations
6-12 November	American Society for Horticultural Science, Orlando, Florida	
	(H. J. Swartz[1]) R. J. McNicol (B. Hyman)	Progress in *Rubus* breeding at Maryland Oral presentation by H. J. Swartz
11 November	Scottish Mycology and Plant Pathology Club, University of Stirling	
	A. M. Campbell	Production of protoplasts of *Phytophthora infestans*
	A. C. Newton	Laboratory measurement of partial resistance to mildew in barley and genetic adaptation
16-19 November	1987 British Crop Protection Conference — Weeds, Brighton	
	H. M. Lawson (J. S. Wiseman)	Crop tolerance to trifluralin and isoxaben, applied alone or in mixture with napropamide, as late winter herbicide treatments in established strawberry and raspberry

[1]Visiting Worker

1-3 December	EUROSTAT meeting on the development of statistical expert systems, Luxembourg	
	M. Talbot	Development of an expert systems toolkit for routine data monitoring
3-4 December	EC Coordination meeting for agricultural research — NIR ring test on grass silages, Brussels	
	G. Wetherill (C. Paul)	Results of the 1st European NIR ring test on grass silages
14-16 December	Association of Applied Biologists Conference on Cereal Quality, Churchill College, Cambridge	
	R. P. Ellis	Breeding for Malting Quality
	K. Taylor (J. S. Swanston)	Malting quality assessment in a Petri-dish
	W. T. B. Thomas (J. S. Swanston) (K. Taylor)	The effects of a delayed harvest on the yield and quality of some spring barley cultivars
17 December	Association of Applied Biologists, Imperial College, London	
	T. J. W. Alphey (G. D. Lyon) (W. M. Robertson)	Nematicidal activity of a natural plant product
	B. Boag (T. J. W. Alphey)	Competition — does it limit the size of nematode populations?
	J. M. S. Forrest (Y. Spiegel[1]) (W. M. Robertson)	Intervention in the host finding processes of the potato cyst nematode *Globodera rostochiensis*
	L. Leach[2] (P. B. Grahan[2]) (D. L. Trudgill)	Ultrastructural changes preceding ecdysis in the fourth stage juveniles of *Goodeyus ulmi* — a free living nematode
	L. V. Lopez Llorca[3]	A sequential study of the colonisation of females and cysts and egg-infection of the cereal cyst nematode (*Heterodera avenae* Woll.) by endoparasitic fungi
	A. T. Ploeg[3] (D. J. F. Brown)	Preliminary studies on the transmission of field isolates of Tobacco Rattle Virus by individual trichodorid nematodes
	W. M. Robertson (J. M. S. Forrest) (Y. Spiegel[1])	Lectin labelling of *Longidorus elongatus*

[1]Volcani Center, Bet Dagan, Israel
[2]Biology Department, Kings College, University of London
[3]Research Student

Conferences organised

R. P. Ellis organised a meeting of the Scottish Society for Crop Research, Considerations and prospects for breeding, producing and marketing cereals, Dundee, 27 January.

R. J. A. Exley and D. K. L. MacKerron jointly with the PMB organised a conference, Towards Improved Seed Potato Production, Dundee, 25 March.

R. A. Kempton organised 150th meeting of the Biometric Society (British Region) to celebrate the award of Honorary Life Membership of the Society to Professor D. J. Finney, University of Edinburgh, 14-15 May.

H. M. Lawson and F. B. Reid[1] organised a Poster and Exhibits Session at the Crop Protection in Northern Britain 1987 Conference, Dundee, 15-17 March. H. M. Lawson also organised a session on Herbicide Resistance in Crops and Weeds at the 1987 British Crop Protection Conference — Weeds, Brighton, 16-19 November.

M. A. Mayo was co-organiser of the Plant Virology Workshop held, during the Society for General Microbiology meeting, 9 April, St. Andrews.

W. P. Mowat was a co-organiser of the Symposium on Fungus-transmitted Viruses and Their Vectors held by the Association of Applied Biologists and the British Society for Plant Pathology, 25-27 August, St. Andrews.

M. C. M. Perombelon was a member of the Executive and organising committee of the Fallen Leaf Lake Conference on Erwinia, 17-20 September.

D. A. Perry was a member of organising committee of the Conference on Crop Protection in Northern Britain, Dundee, 17-19 March.

W. Powell organised the Edinburgh Biotechnology Forum on Genetic Manipulation in Plants held at SCRI Pentlandfield, 18 March.

J. S. Swanston was a member of the organising committee for the Association of Applied Biologists Conference on Cereal Quality at Churchill College, Cambridge, 14-16 December.

P. D. Waister and P. A. Gill organised a 2 day meeting on coordination of R & D in potato physiology in the UK, at the University of St. Andrews, 18-19 June.

C. J. Williamson organised a meeting on Research Objectives for Organic Farming at SCRI, 4 June.

Courses Organised or Contributed to

J. R. Hillman gave courses of lectures to first-year Biological Sciences students at the University of Dundee in January, November and December, and a course of lectures to second-year Biological Sciences students at the University of Strathclyde in December. He also presented a series of lectures for the Botanical Society of Edinburgh at the Universities

[1]Shell Chemicals UK Ltd

of Aberdeen, Dundee, Edinburgh, Glasgow and St. Andrews, 16-20 November. He gave a lecture to the National Farmers Union of Scotland at Blairgowrie, 2 March. He gave the Introductory lecture in Dundee to the Crop Protection in Northern Britain Conference, 17 March. He presented a seminar on employment prospects for plant scientists, Botany Department of University of Edinburgh, 9 March. He gave the concluding lecture, Edinburgh Plant Biotechnology Forum on the Genetic Manipulation of Plants, 18 March. He presented his Inaugural lecture, University of Dundee, 28 May. He gave a lecture to Scottish Seed Potato Development Council Meeting at Aviemore, 13 November and also a lecture to Scotia Agricultural Society, Edinburgh, 28 November.

W. I. A. Jack with rector of Harris Academy organised Work Experience courses for two pupils, 5 January-June.

H. M. Lawson presented a paper on Herbicides for Fruit and Vegetable Crops — Utilising the Herbrex Data-base, to the annual conference of the Chemical Spraying Company at Crieff on 4 February.

H. M. Lawson lectured on Weed Control Strategies for Potatoes to NOSCA 2nd year degree students on 10 March.

G. R. Mackay gave four lectures in a course (10 lectures) on Plant Breeding which he organised at the University of St. Andrews, 9-13 February.

J. A. T. Woodford contributed a lecture and practical on Potato Aphids and the Control of Aphid-borne Viruses for the Pest Module of the BASIS training course at WSAC, Auchincruive on 22 October.

Several members of Virology Department delivered lectures in a short course on plant viruses given to students at the University of Dundee.

Courses attended

K. Anderson attended a Fortran Programming course at ERCC from 16-20 March.

E. M. Burnett attended a Potato Roguing course at Elmwood College, Cupar 22 June-3 July.

A. M. Campbell attended an introductory workshop on Techniques in Molecular Biology; Protein Workshop, Hatfield Polytechnic, 14-15 September.

J. T. Bennett, B. Fleming, E. A. M. Gardner, A. E. Grant, J. G. Guthrie, A. D. Lindsay, P. T. Logie, A. Nicoll, R. Ogg, B. D. Robertson, D. L. K. Robertson, P. W. Yeaman attended courses on safe use of Pesticides and Hand-held Applicators [Knapsack] organised by Sidlaw Training Group in co-operation with A T B on 30 November-2 December.

C. C. Carrie, J. R. K. Bennett, C. R. Dalrymple, W. D. J. Jack, W. W. Killoch, A. W. Mills, D. S. Petrie, D. G. Pugh, L. A. McNicoll, G. G. Pollock attended courses on safe use of pesticides and field crop sprayer [hydraulic nozzle] organised by Sidlaw Training Group in co-operation with A T B on 2-4 December.

I. A. Cowe, M. J. Allison, W. Matheson, D. C. Cuthbertson, H. Bain and W. M. Stein attended a short course on Nuclear Magnetic Resonance Spectroscopy at University of Dundee on dates in October and November.

R. Forrest and J. Heilbronn attended a course on Preparative Aspects of HPLC, at University of Leicester, 7-8 April.

R. J. Killick attended two Civil Service College courses; Financial Accounting for Managers/Administrators, 21-25 September and Management Accounting and Budgeting, 7-9 December. During the summer he also took the Open University course Accounting and Finance for Managers.

G. R. Mackay attended a course on Molecular Genetics of Plants, Bristol University, 22-24 April, Bristol University Department of Extramural Studies.

W. Matheson attended a course on Software for the ARL 3510 Plasma Emission Spectrometer at Wingate House, Luton on 4-6 March 1987.

W. Powell attended a course, Plant Molecular Biology held at Wye College, University of London, 6-15 July.

D. Ritchie and W. Wilson both attended Modules 1&2 of the National Proficiency Test Scheme for Pesticide Application.

G. W. Robertson attended a course on recent advances in capillary chromatography and elemental analysis at Edinburgh on 28 April sponsored by Fisons plc. He also attended a course on the theory, instrumentation and applications of supercritical fluid chromatography held at Bellshill, Lanarkshire on 4 November sponsored by Anachem Ltd.

A. Young attended a Field Trials Workshop — problems of experiment design and analysis, University of Warwick, 31 March, sponsored by the Association of Applied Biologists.

G. R. Young and S. D. Porter attended a Cereal Crop Disease Identification course at NIAB HQ, Cambridge, 16 June.

Editorial Duties

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 *Annals of Botany*
J. R. T. Hodgkin	Joint Editor of *Eucarpia Cruciferae Newsletter*
R. A. Kempton	Associate Editor of *Biometrics*
R. J. Killick	Editor of *Crop Research* Editor of *Potato Research*
H. M. Lawson	Associate Editor of *Journal of Horticultural Science*
M. A. Mayo	Editor (plant virology) of *Journal of General Virology*
G. R. Mackay	Member of Editorial Board of *Heredity*

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*
D. J. Robinson	Member of Editorial Board of *Journal of Virological Methods* Member of Editorial Board of *Journal of General Virology*
P. B. Topham	Editor of *Crop Research*
D. L. Trudgill	Consulting Editor of *Plant and Soil*
P. D. Waister	Associate Editor of *Journal of Horticultural Science* Associate Editor of *Crop Research*
A. B. Wills	Member of Editorial Board of *Crop Research* Joint Editor of *Eucarpia Cruciferae Newsletter*
J. A. T. Woodford	Member of Editorial Board of *Annals of Applied Biology*

Service on Committees

H. Barker	AAB Virology Group Committee
B. Boag	Member of the Ecology Committee of the Society of Nematologists Nematology and Scottish representative on the European Invertebrate Survey Committee
J. E. Bradshaw	Technical Secretary Breeding and Evaluation Sub-Group Grassland and Forage Research Consultative Committee
R. M. Brennan	NFT Black Currant Panel
D. J. F. Brown	Secretary and Treasurer of the European Society of Nematologists
C. P. Carroll	Vice-Chairman, National Whitley Joint Sub-committee of AFRS on Health & Safety at Work
M. R. Cormack	NFT Scottish Fruit Panel
M. F. B. Dale	Convener, Plant Breeding Committee of AAB
J. M. Duncan	BSPP Council Member
R. P. Ellis	SSCR Technical Secretary Cereals Group BSPB Cereal Crop Group BSPB Representative on SAC Recommended List Consultative Committee BSPB Representative on Institute of Brewing Scottish Working Party
M. F. Franklin	Biometric Society (British Region) Committee
P. A. Gill	IOH Secretary of Scottish Branch

S. C. Gordon	Member of the AFRC Pesticide Application Discussion Group Member of the AAB Pesticide Application Group Committee
B. D. Harrison	Advisory Committee, *Advances in Virus Research* Virology Programme Committee, International Congress of Plant Pathology
J. R. Hillman	AFRC Plants and Soils Research Committee AFRC Computing Committee DAFS Joint Management Board Chairman DAFS Joint Management Board Computing Policy Review Group ECRE Board of Management GIUS, WSAC, 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 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 Horticultural Quartet BSPB Technical Advisory Committee
W. I. A. Jack	NFT Scottish Soft Fruit Panel
D. L. Jennings	NFT Raspberry Panel NFT Scottish Soft Fruit Panel SNSA Adviser to Committee
A. T. Jones	ISHS Secretary of Working Group on Virus Diseases of Small Fruits
R. A. Kempton	Secretary, Biometric Society (British Region) Royal Statistical Society Council Royal Statistical Society Research Committee
H. M. Lawson	ADAS/IACR(LARS) (Weed Research Division) Liaison Group AFRC Fruit Weed Control Group BCPC R & D Sub-committee — Weeds SAC/SCRI Weeds Group

W. H. Macfarlane Smith	BSPB Oilseed and Industrial Crop Group NPTC Plant Variety Development Panel Secretary SCRI/ASS/COSAC Forage Brassica Working Group Secretary SCRI/SSCR Forage Crop Sub-committee
G. R. Mackay	Member of Interdepartmental and Users Committee of DAFS Potato Quarantine Unit Member of BSPB Potato Crop Group Member of DAFS Potato Working Group
D. K. L. MacKerron	Secretary DAFS Potato Working Group Secretary SSCR Potato Crop Sub-committee Chairman Working Group on Water relations in Potato Production, EAPR Physiology and Agronomy Sections
R. J. McNicol	NFT Strawberry Panel NFT Scottish Soft Fruit Panel NFU Strawberry Breeding Sub-committee to the Soft Fruit Committee EMRS Strawberry Research Workshop
B. Marshall	SEB Plant Biology Section Committee Maximum yield/yield constraints of Cereal Working Group
W. P. Mowat	Convener, SNSA Bulb Technical Committee
A. F. Murant	International Committee on Taxonomy of Viruses, Member of Executive Committee and Plant Virus Sub-Committee
A. C. Newton	UK Cereal Pathogen Virulence Survey — Committee Member
M. C. M. Pérombelon	Chairman, International Erwinia (soft rot) Group
D. A. Perry	Treasurer, Association for Crop Protection in Northern Britain
M. S. Phillips	AAB Nematology Group Committee
I. M. Roberts	Chairman, AFRC Electron Microscope Advisory Group Safety Representative, Royal Microscopical Society Education Committee
M. Talbot	Technical Working Party on Automation and Computer Programs, International Union for the Protection of New Varieties of Plants
D. L. Trudgill	Chairman and Convener of EPPO *ad hoc* Committee on Potato Cyst Nematode

P. D. Waister	Chairman DAFS Potato Working Group
	Co-Chairman EAPR Working Group on Tuber Numbers
	PMB Research and Development Committee (AFRC Consultant)
	SCRI/ASS/COSAC Liaison Group
	University of Dundee Botanic Garden Committee
R. L. Wastie	Convener of Scottish Mycology and Plant Pathology Club
A. B. Wills	Chairman SCRI/ASS/COSAC Forage Brassica Working Group
	SCRI/ASS/COSAC Liaison Group
J. A. T. Woodford	Scottish Regional Secretary, Royal Entomological Society of London
	Secretary, Scottish Potato Aphid Working Party

Exhibitions and Poster Sessions

30-31 January	*Royal Society of Edinburgh Conversazione*, University of Dundee
	Demonstration of interactive viewdata crop management system
	Detection of potato leafroll virus by ELISA
	The Comparamill for measuring malting quality in barley
13-17 February	*Scottish Trade Fair*, Oporto, Portugal (Scottish Seed Production Council)
	Seed health : seed performance : seed suitability
17-19 March	*Crop Protection in Northern Britain 1987*, University of Dundee
	Weed emergence and growth in response to date of autumn seedbed preparation
	Herbrex
18 March	*Edinburgh Biotechnology Group*, Edinburgh
	Barley breeding at the Scottish Crop Research Institute
5-10 April	*Gentner Symposium on Biology of Complex Carbohydrates*, Rehovat & Eilat, Israel
	Surface carbohydrates on the outer cuticle of *Anguina tritici*
9-10 April	*SGM Meeting*, St. Andrews
	Kinetics of accumulation of T and B components of raspberry ringspot virus in infected protoplasts
	Potato leafroll virus multiplies in non-phloem tissue of *Nicotiana clevelandii*

14-15 April	*Potato Marketing Board*, Spring demonstration, Lincoln Breeding for potato cyst nematode resistance Predicting the performance of the potato crop Sources of seed tuber contamination by soft rot erwinias
11-14 May	*GCIRC 7th International Rapeseed Conference*, Poznan, Poland Eleven years of Eucarpia Cruciferae Newsletter
14-15 May	SASS Demonstration, Edinburgh
23-24 May	*Rotary Club*, Forfar Tayberry
6-9 July	*AFRC Science into Practice Exhibition*, Royal Show, Stoneleigh, Warwick Predicting the performance of the potato crop
26-31 July	*10th Triennial Conference of the European Association for Potato Research*, Aalborg, Denmark Water-related problems limit yield and quality of potatoes Factors influencing number of tubers per stem
29-30 July	*2nd International Symposium on Nitrate Assimilation*, University of St. Andrews Molecular and genetic aspects
9-14 August	*7th International Congress of Virology*, Edmonton, Canada Molecular studies of potato leafroll virus Whitefly-transmitted geminiviruses from India
14-17 September	*British Society of Soil Science*, Autumn meeting, Auchincruive Some problems in predicting the availability of soil micronutrients to crops
13-15 October	*British Laboratory Week*, Olympia Exhibition Centre, London Determining malting quality in barley: a demonstration of the Comparamill
14 October	*Scotgrow 1987*, Ingliston, Edinburgh Fungus diseases of raspberry New SCRI soft fruit cultivars Virus-tested narcissus
20 October	*Society of Chemical Industry Agriculture Group Symposium* The role of nitrogen fertiliser in the mobilisation of potassium in the soil solutions of winter barley

11 November	*15th Scottish Symposium on Electron Microscope Techniques,* Heriot Watt University, Edinburgh Fungal endoparasitism of cereal cyst nematode (*Heterodera avenae*)
16-19 November	*1987 British Crop Protection Conference — Weeds,* Brighton HERBREX
27-28 November	*Mammal Society Symposium on Mammals as Pests, Regents Park Zoo, London* Population dynamics of parasites of wild rabbits (*Oryctolagus cuniculus*)
14-16 December	*Association of Applied Biologists Conference on Cereal Quality,* Churchill College, Cambridge Malting quality assessments from a Petri dish The effect of a delayed harvest on yield and quality of some spring barley cultivars

Radio and Television

11 March	*BBC Radio Scotland (Schools), Let's Talk*	
	G. R. Mackay	The mighty spud
April	*BBC World Service*	
	B. D. Harrison	Genetic engineering of virus resistance in plants
June	*French Overseas Service*	
	B. D. Harrison	Cause and control of cassava mosaic disease
8 June	*BBC Radio Scotland, Science File*	
	G. R. Mackay C. J. W. Torrance	Crisping quality in potatoes
10 June	*BBC Radio Scotland, Science File*	
	G. R. Mackay C. J. W. Torrance	Crisping quality in potatoes
22 July	*BBC Radio Scotland*	
	M. R. Cormack	Pattenden 'Harrier' raspberry harvester at SCRI
23 July	*BBC Radio Scotland*	
	M. R. Cormack	Pattenden 'Harrier' raspberry harvester at SCRI
23 August	*Tyne Tees Television, Turning the Tide* Potato Breeding Department	
1 September	*BBC Radio Scotland*	
	B. D. Harrison	Use of satellite nucleic acid to engineer virus resistance in plants
5 December	*BBC Radio 4, The mighty spud* Potato Breeding Department	

PU 1 To provide improved cultivars of potatoes and more efficient breeding methods

(a) Breed improved cultivars of potato for the UK.
(b) Breed potatoes for export potential and select suitable cultivars by overseas trialling.
(c) Study the genetics of potatoes and improve breeding and trialling methods.
(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 2 To provide improved cultivars of cereals and more effective breeding methods

(a) Breed cultivars of spring barley with improved adaptation to northern Britain and with good malting quality.
(b) Breed cultivars of winter barley with improved adaptation to northern Britain and with good malting quality.
(c) Study biochemical genetics of barley.
(d) Study genetics of barley and develop breeding methods.
(e) Improve, and use on barley breeding material, screening methods for fungal disease resistance.
(f) Develop rapid tests for malting quality.
(g) Trial extension crops.

PU 3 To provide improved cultivars of soft fruit and more effective selection methods

(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 strawberry genotypes from the IHR (East Malling) programme, adapted to the Scottish environment.

PU 4 To provide improved cultivars of forage crucifers and more effective breeding methods

(f) Multiply and stabilise breeder's selections: and trial selections in collaboration with other organisations.
(g) Investigate novel combination of genomes to produce breeding materials.
(h) Investigate tissue culture and new methodologies and use them to produce breeding materials.
(i) Study genetics of brassicas and formulate improved breeding methods.
(j) Study S-allele incompatibility in brassicas.
(k) Devise, and use on brassica breeding material, screening methods for fungal and disease resistance.
(l) Develop and use screening tests for important compounds in brassica breeding material.
(m) Breed improved brassica root crop cultivars and investigate breeding methods.
(n) Breed improved leafy forage brassica cultivars and investigate breeding methods.

PU 5 Potato physiology

(a) Investigate the physiology of the response of the potato crop to radiation, temperature and water supply.
(b) Physiological processes involved in dry matter partitioning in the potato plant.
(c) Physiological and metabolic factors that influence sprout growth during the pre-emergence growth phase.
(d) Mathematical analysis and modelling of plant and crop processes.
(e) Effects of mineral nutrition on growth and development of potatoes.
(f) Factors affecting dry matter content and sugars balance of potato tubers.
(g) Investigate the phasing of inter- and intra-plant competition in the potato crop.
(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 involving 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 accummulation and calcium-related internal disorders.

PU 6 Husbandry of soft fruits

(a) Physiological factors affecting the maturation and quality of raspberry 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 soft fruits including raspberry, other *Rubus* species, and blueberries.

PU 7 Environmental and cultural factors influencing yield and quality of arable crops

(a) Effects of cultural practices on the growth and development of the potato crop.
(b) Effects of cultural practices, environment, and genotype on development, growth and quality of grain legumes.
(d) Inputs required by mathematical model to predict national potato crop.

PU 8 The biology and control of diseases and pests of barley crops in northern Britain

(a) Investigate the biology of over-winter root diseases to improve control strategies.
(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 9 The biology and control of diseases and pests of soft fruit crops in northern Britain

(a) Improve control by studying the biology of fungal and bacterial diseases of *Rubus*.
(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.
(g) Determine the cause of, and devise diagnostic measures for, June Yellows of strawberry.

PU 10 The biology and control of diseases and pests of forage crops in northern Britain

(a) Develop control measures by studying the biology of fungal diseases of forage brassica crops.
(b) Develop and evaluate screening tests for resistance to turnip root fly.
(c) Investigate the pathogenicity and control of nematode pests of forage brassicas.
(d) Develop diagnostic, screening and control methods for forage brassica viruses.

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 field propagation.

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

(a) Devise detection and diagnostic methods for, and characterise, whitefly-transmitted viruses from tropical crops.

PU 13 The biology and control of diseases and pests of potatoes in northern Britain .

(a) Study the biology and assess the effects of bacterial diseases of the growing potato plant.
(b) Study the biology of bacterial diseases of stored potato tubers.
(c) Elucidate mechanisms of quantitative resistance to potato diseases.
(d) Elucidate survival of potato pathogens by studying their autecology.
(e) Devise methods to control diseases of potato.
(f) Ecology of aphid vectors and epidemiology of aphid-borne potato viruses.
(g) Devise methods of controlling virus spread in potato.
(h) Improve management of nematodes in seed and ware land and reduce damage in ware land.
(j) Understand and assess effectiveness of virus resistance mechanisms in potato.
(k) Devise and improve virus detection methods; examine occurrence, variation, transmission and ecology of potato viruses.

PU 14 Ecological aspects of weeds, pests and pathogens leading to control methods

(a) Prediction of weed populations and herbicide performance in crop rotations.
(b) Ecology and control of weeds, volunteer crops and unwanted crop vegetation in agricultural and horticultural crops.
(c) Ecology and population dynamics of plant-parasitic nematodes.
(e) Genetic control of pathogenesis and factors affecting changes in physiological races.
(f) Determine the interactions among the soil biota that affect major root pathogens and pests, and root function.
(g) Determine the factors influencing the effectiveness and specificity of nematophagous fungi attacking cyst and other nematodes.

PU 15 Host-parasite and vector mechanisms

(a) Mechanisms of resistance and susceptibility to insects and nematodes.
(b) Identify and elucidate the effects of pre- and post-formed host and pathogen compounds disease resistance.
(c) Host and pathogen interactions; factors determining latency and host resistance.
(d) Mechanisms and genetic basis of virulence in potato cyst nematodes.
(e) Elucidate mechanisms of virus retention and specificity and effect of vector behaviour on efficiency of transmission.
(f) Elucidate mechanisms of virus transmission by aphids.
(g) Elucidate the genome organisation of viruses and molecular aspects of their biological properties.
(h) Enhance virus resistance by transforming plants with sequences derived from virus or satellite nucleic acids.
(i) Elucidate the role of neurosecretion in the development of nematodes.
(j) Investigate the control of nematode by nematotoxic chemicals.
(k) Determine structure and function of the genome RNA of potato leafroll virus.

PU 16 Development of experimental techniques

(a) Develop NIR analysis to predict specific biochemical components in crops, pathogens and host/parasite interactions.
(b) Devise and improve methods for the electron microscopy of viruses, and virus vectors.
(c) Devise and improve methods for detection and diagnosis of plant viruses and viral materials.

PU 17 Root form and function of potatoes and interactions with the microflora in soil

(a) Root growth and distribution in relation to assimilate supply and soil physical and chemical environment.
(b) Dry matter losses from roots.
(c) Nitrogen cycling through the biomass, and plant uptake and distribution.
(d) Potassium and calcium uptake, distribution and physiological roles.
(e) Co-ordination of quantitative data on root growth and function.
(f) Analysis of biomass components and their contribution to plant nutrition in arable soils.
(g) Interactions within the rhizosphere of micro-organisms beneficial and detrimental to plant growth.
(h) Microbial pathogens of plant parasitic nematodes.

CEREAL BREEDING

N. L. INNES

As Government policy is to encourage the privatisation of commercial cultivar breeding, either leaving the production of new cultivars to the private sector or ensuring that the cost of commercial cultivar breeding at an Institute such as SCRI is borne by private companies, the move to more fundamental and strategic research was accelerated. Meanwhile, new improved cultivars continue to emerge from the barley breeding programmes, and one spring barley line has been entered by SCRI and DAFS for National List Trials in 1988. With the privatisation of NSDO, alternative marketing partners for SCRI's new cultivars are being sought.

A considerable proportion of departmental effort was directed towards providing a better understanding of the physical and chemical attributes of barley grain in relation to malting quality, and to developing improved breeding strategies with high malting quality as one of the main aims. Central to this work was a search for speedier, more efficient and relatively simple screening tests that reflect malting quality as measured by the fermentable material obtained by extraction in hot water. Funds for some of this research were provided by the HGCA. A strong collaborative programme on starch research is being developed with W. R. Morrison of the University of Strathclyde.

Spring barley breeding [PU 2(a)]

Cv. Heriot was placed on the Institute of Brewing's List of preferred cultivars for Scotland in recognition of its good malting and distilling characteristics. However, newer cultivars have higher yield potential, so Heriot has been removed from the Scottish Agricultural Colleges (SAC) Recommended List for 1988. As cv. Tweed is also being outclassed by newer cultivars, it too has been removed from the same list. Cv. Tyne performed well in the SAC Recommended List Trials in 1987, yielding 105 and 109% of the control mean in untreated and fungicide treated trials respectively. It continues to exhibit good resistance to powdery mildew and it is similar to, or slightly better than, the popular cv. Golden Promise in all other agronomic respects. Hot water extract is similar to, or slightly better than, that of Golden Promise. Tyne was placed on the National List and awarded Plant Breeders Rights in 1987 and has been recommended by SAC for growing in Scotland in 1988. Cultivar x nitrogenous fertiliser rate trials during the period 1985-87 indicated that Tyne may be well suited to lower input systems.

A number of lines in Joint Main Trial (JMT) in 1987 outyielded the best control (cv. Regatta) but most were either non-uniform, weak-stemmed or of poor quality. However, one line, TS 275/3/6 from the cross cv. Nairn x cv. Harpoon, yielded 113% of the mean of the control cultivars Klaxon and Natasha over all trials in 1987 and as it has good malting quality and straw strength it has been entered for National List Trials for 1988. Micro-malting tests from two trials in 1986 showed that it produced levels of hot water extract that were only slightly inferior to those from Natasha. It has good resistance to powdery mildrew, *Rhynchosporium*, yellow rust and brown rust but it is late maturing.

Eighteen lines in primary trial yielded consistently better than the controls and have been retained for further trials and multiplication. Normally, they would have been entered into JMT but, with the privatisation of plant breeding at the Plant Breeding Institute, Cambridge, this valuable trial series has been discontinued. Other arrangements have been made to test these lines in England and Wales. Forty selections were made from second year yield trials and 10 single plants from each selection were multiplied in New Zealand in 1987/88. The best of these will be entered into primary trials and multiplied in 1988, together with five doubled haploids selected from a sample produced by W. Powell[1] from the F_1s of some crosses by the application of anther culture techniques. These crosses had shown promise in cross prediction studies.

Twenty-five entries were grown in a split-plot trial of two replicates with two main plots: untreated and fungicide treated, to examine the response of 18 SCRI cultivars and seven controls to fungicide treatment. Two sprays were used as the fungicide treatment, one at G.S.30 and the other at G.S.39. Whilst the fungicide treatment did not totally control a heavy epidemic of powdery mildew it increased yield by an average of 1.29 t/ha with several susceptible controls showing increases in excess of 2 t/ha. In general, the SCRI cultivars were less responsive than the controls, reflecting their better levels of disease resistance. Preliminary analysis of the effect of this fungicide treatment on components of malting quality showed that it led to the production of grain with higher milling energies that may not malt so readily. Micro-malting tests are being conducted to determine whether or not the treatment had any effect upon the levels of hot water extract. Dormancy was unaffected by fungicide treatment.

The same entries were grown in a similar trial design, but the main plots were normal and late harvest dates, to assess the relative resistance of cultivars to yield loss from delayed harvest. The late harvest was 3 weeks after the normal harvest and the average yield was reduced by 0.48 t/ha. Some cultivars showed losses of nearly 1 t/ha but others were unaffected by the delay. Ear loss was more severe than grain loss and was the most important factor in contributing to yield loss. Further analysis of previous

[1]Tissue Culture Department

harvest date trials demonstrated that yield loss, increased screenings and higher grain nitrogen content arising from harvest delay was much more marked in cultivars that possessed the *denso* dwarfing gene (e.g. cv. Triumph). The decrease in hot water extract was less in this group when harvest was delayed but further breeding work is necessary to improve the straw characteristics of genotypes carrying this dwarfing gene.

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

The exploitation of resistance to powdery mildew in *Hordeum spontaneum* [PU2 (d)]

Resistances to powdery mildew found in a number of *H. spontaneum* lines have been transferred to a more suitable agronomic background by backcrossing with cv. Golden Promise as the recurrent parent. Ninety powdery mildew resistant BC_3F_5 lines from this programme together with 10 controls, including Golden Promise, were grown in a field trial in 1986. The primary aim of the backcrossing programme had been achieved, in that high levels of powdery mildew resistance had been transferred into the Golden Promise plant type. In addition, the mean performance of the lines was superior to Golden Promise for ear emergence, yield and thousand grain weight and was comparable to that of all the controls. The superiority of the lines compared to Golden Promise appeared to be due to residual variation associated with *H. spontaneum*, as the characters in question were either weakly or not correlated with mildew resistance, suggesting that pleiotropy and/or linkage effects were either absent or having a low effect. The lines generally had higher milling energies than the controls, suggesting that their malting qualities were poor. As there was no correlation between mildew resistance and milling energy, further breeding work should lead to the production of good malting quality lines incorporating these resistances.

(W. T. B. Thomas, G. R. Young, J. S. Swanston)

Winter barley breeding [PU2 (b)]

The objectives of the winter barley breeding programme briefly outlined elsewhere (*Ann. Rep. 1986*, 48) include the provision of new cultivars which are well adapted to the colder and wetter climate of northern Britain. The variability of such conditions was well illustrated by the contrasts between the cold winter of 1985/86 and the milder temperatures experienced in 1986/87. This resulted in a lower level of frost damage but higher levels of powdery mildew. Early scores of leaf damage, supposedly due to frost, were closely related to later mildew scores. The majority of plots were well established from timely sowings: the only problem was the uneven depth to which some plant rows were drilled in a stony seedbed. As in 1986, the autumn sown trials showed reasonable coefficients of variation and overall were more consistent than spring sown crops.

Little *Rhynchosporium* occurred but most genotypes succumbed to a heavy mildew epidemic with only cv. Pipkin of the established cultivars showing reasonable resistance. As in previous years, disease scores on material sent to IGAP (Welsh Plant Breeding Station) were invaluable in providing a balanced selection programme for resistance to all the important disease of winter barley.

A pilot study investigated the prediction of the value of 30 crosses by the observation of 20 replicated F_5 rows from each cross grown under both low and normal levels of nitrogen fertilizer so that performance under different regimes could be assessed. Useful information was gained on the resistance of lines to mildew and *Rhynchosporium*, height, maturity and lodging. Yield was also measured and used to rank crosses but differential reaction to frost damage, as some crosses were between parents with spring and winter habit, caused considerable variation in plant population and complicated the interpretation of the results.

As in 1986, lines in advanced trials were tested at sites in East Lothian and Aberdeenshire as well as at Mylnefield but with somewhat different results. At The Murrays farm, East Lothian, all the lines lodged severely due to a combination of a high level of nitrogen topdressing and heavy rainfall. In the Aberdeenshire trial disease was controlled, so yields were greater than at Mylnefield. Of 10 winter barley lines to be entered into stocks multiplication in 1986 four showed sufficient promise in 1987 trials to be sown as progeny rows in 1987 for harvest in 1988.

Studies of the effect of sowing date on plant development and grain yield in winter barley were continued but the format of the trial was modified to include plots without fungicide treatments. This necessitated using fewer cultivars. To ensure a good contrast within the experiment for frost resistance, cultivars Golden Promise and Heriot were included. Heriot had been grown in 1986 and showed much lower yield potential than cv. Gerbel. In 1987 Golden Promise showed greater susceptibility to frost damage than did Heriot.

(R. P. Ellis, S. D. Porter)

Biochemical genetics of milling energy [PU2 (c)]

The hardness of a barley endosperm, as measured by its milling energy (*Ann. Rep. 1986*, 150), is related to malting potential. Work started on a project financed by the Home Grown Cereals Authority (HGCA) to examine the ultra-structural and biochemical mechanisms involved in determining hardness. The inheritance of these characters will be investigated.

Grain from 11 cultivars was sieved into four size-fractions and these were milled with the SCRI Comparamill. Preliminary results indicated that while different cultivars have characteristic milling energies, within a cultivar grains between 2.0-2.5 mm are the hardest. Larger grains are slightly softer

and smaller grains are much softer. Natasha, a cultivar that malts well, showed the least variation in hardness between grain fractions.

(J-P. Camm[1], R. P. Ellis, W. R. Morrison[2])

Modelling barley development and yield [PU 2(d)]

A collaborative project with IFS funds was started between SCRI and Edinburgh School of Agriculture to model growth and development in barley. Simulation modelling will be used to quantify the effects of environment on grain yield and to investigate the suitability of existing and new cultivars for use in Scotland. The existing trials system is limited by time and resources and the extrapolation of results to other sites and seasons is unreliable. Field trials in Scotland are concentrated around research centres and do not reflect the full divesity of the barley growing areas.

Initial work has concentrated on exploring the progress of research on existing 'whole crop' models. There is a considerable body of literature on wheat modelling, but little on barley. The CERES family of models, developed as part of the International Benchmark Sites Network for Agrotechnology Technology Transfer predicts yields for a number of crops over a wide range of latitudes given detailed edaphic, climatic and crop management data. A prototype model developed from the CERES models is being validated for Scottish barley crops.

In the CERES model cultivars are specified by six genetical parameters and the examination of theoretical cultivar values will be useful in designing breeding programmes. The model will also identify areas of further search for increasing knowledge of crop physiology.

(R. P. Ellis, G. Russell[3], G. Wilson[3])

Malting quality characters and breeding strategies [PU 2(c)]

The adverse affect on malting quality due to the introgression of genetic factors associated with resistance to certain diseases (*Ann. Rep. 1985*, 45) has indicated the need for greater knowledge of the location of genes determining quality characters. Consequently, a series of crosses between morphological genetic marker stocks and the malting cv. Carina was made. Field scoring of the F_3 generation enabled observation of the segregation of certain of these markers. Laboratory work with further markers and assessment of quality components is continuing.

Crosses have also been made between the cultivars Keg and Klares, which are designated of good malting quality in the UK and Canada respectively. The former is characterised by a very soft endosperm. In SCRI malting tests, the latter produced a higher hot water extract than

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[3]Edinburgh School of Agriculture

would be expected from its endosperm characteristics. It ranked highly, however, in tests to assess the extent of endosperm modification following germination. Progeny which combine soft endosperms with rapid modification will be selected, using a series of small-scale tests, and assessed for rate of modification during, and extract obtained following, malting. This technique of combining individual complementary components will also be assessed as an alternative to the present breeding strategy where malting quality like yield, is assessed as a single character following laboratory scale malting and individual components are not considered.

(J. S. Swanston)

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

The reliability of the improved Comparamill (*Ann. Rep. 1986,* 150) has enabled reliable, measurement of the milling energies of the large numbers of samples grown in cross prediction studies. Trivariate predictions were made of the numbers of lines that were likely to be produced from a cross that would be higher yielding, shorter-strawed and would have lower milling energies than cv. Natasha. These predictions were used to rank the crosses grown in a cross prediction study in 1986. Random inbred lines are being derived from a small number of these crosses to test the effectiveness of the predictions. The results should indicate whether or not milling energy could be used in this way to identify the best malting quality crosses.

(W. T. B. Thomas, J. S. Swanston)

Competition in spring barley [PU 2(d)]

Previous studies have revealed the presence of inter- and intra-genotypic competition effects for agronomic characters and yield and yield components in spaced plant plots of spring barley (*Ann. Rep. 1983,* 50). If such effects were also to be found between rows of spring barley they could seriously affect breeding programmes which rely on selection between rows and the results of cross prediction studies where material is also evaluated in rows.

An experiment was therefore done to determine the presence and relative balance between inter- and intra-genotypic competitive effects using 6 random inbred lines that had not been the subject of any deliberate selection. Each inbred line was sown in plots of 1, 2, 3, 4, 5 and 6 rows to form a monoculture series to determine the intra-genotypic competitive effects. Inter-genotypic effects with other genotypes were determined by substituting 1, 2, 3, 4, or 5 of 6 rows of a genotype by a second genotype in a duoculture series for each of the other five genotypes. Each row from the various monoculture and duoculture series was scored for maturity, height, yield and yield components and the results are being analysed.

(W. T. B. Thomas)

Environmental sensitivity in spring barley [PU 2(d)]

A number of random inbred lines was derived by both doubled haploidy and single seed descent from two barley crosses. As the doubled haploids were produced from the F_1s' they had undergone one cycle of recombination, whereas the lines produced by single seed descent have undergone several cycles. These lines, together with several controls, were grown in four trials in which nitrogen level and fungicide treatments were varied. Two trials had a low level and two a high level of nitrogen applied to them. One trial at each nitrogen level had two fungicide sprays while the other was untreated. As the random inbred lines were produced without any conscious selection, they provide an opportunity to examine the influence of these four treatments upon the environmental sensitivities of several characters. By comparing results from the doubled haploid and SSD derivatives, the magnitude of any linkages can also be determined. The effect of selection in any one of the four trials can also be examined. Unfortunately, the plots lodged badly before harvest, making interpretation of results from plot yields unreliable. Single plants were recovered from each plot and should provide reliable information on the environmental sensitivities of the components of yield.

(W. T. B. Thomas, W. Powell[1], G. R. Young)

Disease Screening [PU 2(e)]

Irrigation was necessary to promote development of disease in the *Rhynchosporium* disease nursery. This caused disease to develop, but belatedly, so worthwhile selection was only possible amongst the spring-sown entries.

Collaboration with IGAP (Welsh Plant Breeding Station) for disease testing continued and is a valuable aid to the SCRI breeding programmes.

(A. C. Newton[2], W. T. B. Thomas, R. P. Ellis)

The milling energy of malted barley [PU 2(f)]

The hot water extract of fermentable material, obtained during the malting and initial brewing processes, depends on endosperm structure and how that structure is broken down, or modified, during malting. The endosperm structures of different cultivars may be rapidly compared by measuring relative grain hardness in a milling energy test. By applying this test to malted barley, where much of the initial hardness has disappeared, it was possible to assess the outcome of modification. As this is the result of both initial endosperm structure and enzyme activity, it provided a much higher correlation with hot water extract ($r-0.92$, $P<0.001$) than that between grain milling energy and hot water extract. ($r = -0.52$, $0.001<P<0.01$).

[1]Tissue Culture Department
[2]Mycology and Bacteriology Department

Malt milling energy does not, however, assess the enzymes necessary to break down the gelatinised starch during a brewery mashing procedure. A rapid technique, to measure ∝-amylase activity, was therefore developed, by quantifying with a nephelometer the change in light scattering properties when a starch solution is broken down. As this method required only 600 mg of malt flour, it can use the flour made during determination of malt milling energy by the Comparamill.

These techniques not only speed up comparison of malts obtained from different barley samples, but greatly reduce the number of full malt analyses required, enabling a great increase in the throughput of the malting quality laboratory. Between four and five times as many malts can now be assessed than before and work is currently directed towards more rapid production of greater numbers of malts.

Part of the work described was supported by a grant from the HGCA.

(J. S. Swanston, K. Taylor[1])

Malting quality assessments on germinated grain [PU 2(f)]

In an effort to develop effective screening methods for malting quality in the early generations of barley breeding programmes, small samples of grain germinated in petri-dishes have been assessed. Milling energy tests of ungerminated grain ignore essential enzymes synthesised during malting, while laboratory scale malting demands too much time and seed to be routinely applied to large numbers of small samples. Although germination in a petri-dish does not permit the same control of embryo growth, or the promotion of endosperm modification, that can be exercised during malting, it is still possible to assess the levels of enzymes present.

Following 5 days' germination, 25 grains were halved longitudinally and then dried for 3 hours at 105°C. After weighing, the grains were extracted in water at 60°C for 1 hour, before being dried for a further 3 hours and then re-weighed. Losses in weight between the two determinations were due to extraction of endosperm cell contents, facilitated by the breakdown of the cell wall and protein matrix during germination. Generally, good malting cultivars showed the greatest weight losses. However, the test also identified certain cultivars, with comparatively hard endosperms, which gave moderate hot water extracts after malting, suggesting that a rapid synthesis to a high level of certain enzymes may partly compensate for poor endosperm characteristics.

Because this test can be performed rapidly and requires only few seeds, it is applicable to early generations and, as it complements the grain milling energy test, will improve selection. Additionally, it provides an opportunity to screen potential parents, cross a genotype with good endosperm properties to one with good enzyme activity, then select progeny combining the two characteristics.

(J. S. Swanston, K. Taylor[1])

[1]Chemistry Department

Trial cereal crops in collaboration with other organisations [PU2 (g)]

The Department was involved in the trialling of five cereal crops: winter and spring barley and oats, and winter wheat.

Winter and spring barley and spring oat trials were grown for the BSPB. Trials of winter wheat and winter oats (1987/88) for BSPB were grown for the first time at Mylnefield for harvest in 1988. Trials of spring and winter oats were undertaken for IGAP (Welsh Plant Breeding Station). Spring and winter barley trials were grown for IPSR (Cambridge Laboratory).

Manganese trace element deficiency continues to be a major problem with trials sown with the Oyjord plot drill, and such trials required up to three foliar sprays of manganese. Investigations are under way to improve fertilizer placement during sowing.

Manganese deficiency and high levels of mildew created problems in the spring barley trials, in which coefficients of variation were unusually high.

(A. Young)

NEW BARLEY CULTIVAR

TYNE

Ownership of the cv. Tyne, for which National Test status and Plant Variety Rights were awarded in 1987, was transferred to the NSDO as part of the agreement for its privatisation.

Origin: A selection from the cross (cv. Goldmarker x cv. Athos) x (Goldmarker x cv. Magnum)

Straw length: 9 cm. shorter than cv. Klaxon. 7 cm. taller than cv. Doublet.

Straw strength: Weaker than cv. Doublet, stronger than Klaxon.

Maturity: Similar to cv. Golden Promise.

*Disease resistance:**

	Tyne	Klaxon
Mildew	8	5
Yellow Rust	(6)	4
Rhynchosporium	4	6
Brown Rust	7	6

Malting quality: Post harvest dormancy — short
Hot water extract — similar to Golden Promise

Yield potential:†

National List Trials 1985/86	Tyne	Klaxon
England and Wales	102%	103%
Scotland	104%	104%

*On a 1-9 scale. High scores indicate greater resistance.

†*Yield potential* values are % of mean of controls in trials without fungicides.

BRASSICA BREEDING

A. B. WILLS

The decision to simplify the name of the Department to Brassica Breeding will give further scope and encouragement to research involving non-forages as model genotypes and for the production of enhanced germplasm with wider relevance than to the forages alone.

Yields of swede and forage rape returned to more typical levels following the exceptionally high yields recorded in the previous season. Most trials suffered from nitrogen deficiency towards the end of the particularly wet growing season. The low natural incidence of powdery mildew on swede and rape probably also reflected the prevailing weather conditions. However, the disease developed well from inoculated spreader plants and satisfactory discrimination of resistance levels was achieved in a field experiment to study the genetics of resistance to powdery mildew in swede.

Success in inducing the production of dihaploid plants of swede from microspores and a significant improvement in the efficiency of production of synthetic *Brassica napus* marked the increased deployment of tissue culture as a tool in genetical studies and plant improvement. Not all the consequences of these non-traditional procedures are positive however. In particular, remarkable variation following crosses to artificial *B. napus* — and even after stringent selection — remains in some advanced generations of rape. Such material also frequently has lower dry matter content.

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

The selection DBOxbbd (SS1) was included in NIAB Vartest Trials for a second year. Bred from cv. Bangholm Magres x cv. Champion, it has good mildew resistance as well as a high yield of dry matter at medium dry matter content (*Ann. Rep. 1985,* 50). SS1 is also winter hardy, with a purple skin, yellow flesh and an attractive appearance, and it has aroused the interest of growers for use as a late-season shopping swede, as well as for stockfeeding. A selection from the traditional shopping swede cv. Acme has also attracted growers although it may not be sufficiently distinct from Acme to be marketed as a new cultivar. However, three F4 generation families with similar potential for culinary use and stockfeeding were identified. These families, from Acme x cv. Marian and Acme x cv. Ruta Øtofte, all have deep purple skin colour, yellow flesh and globe shape. Their dry-matter yields were 11.01, 10.85 and 10.70 t/ha, respectively, compared with 9.97 t/ha for the mean of the control cultivars Angela, Marian, Melfort and Ruta Øtofte.

A selection from the white fleshed cv. Criffel again performed well in New Zealand and is continuing in trial there as a swede for stockfeeding. It has attracted attention as a potential processing swede. Again, should there be distinctness problems, equally suitable high yielding, mildew resistant lines from the cross Bangholm Magres x Criffel have been identified in the F_5 generation.

A yield trial was grown to assess 86 F_4 families from crosses between lines with clubroot resistance derived from the experimental Dutch stubble turnip population ECD04 and lines selected primarily for yield from modern cultivars. The resistance to clubroot of these families was assessed in a greenhouse seedling inoculation test and resistant plants were selected from 15 of them. In the yield trial, the mean dry-matter yield of the 15 families was 11.06 t/ha compared with 10.62 t/ha for the mean of the control cultivars Angela, Marian, Melfort and Ruta Øtofte. Further F_4 families comprising crosses among clubroot resistant lines were also assessed in 1987. Most were agronomically unacceptable and just two with a clubroot disease index of zero, out of the 92 families assessed, will be advanced to F_5.

In order to make further progress in improving yield, quality, disease and pest resistance of swedes for stockfeeding and for human consumption further knowledge is required on the inheritance of these traits and new breeding methods need to be explored [see PU 4(i)].

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

Heterosis in swede [PU 4(i)]

When strains, cultivars and inbred lines of swedes are hybridised, the dry-matter yield of the F_1 hybrid may exceed the better parent by 20-30%, as was found for eight of the 55 F_1 hybrids grown in 1987 to determine the inheritance of mildew resistance. (Data still being analysed). This heterosis is being investigated in order to develop more effective breeding methods for increasing dry-matter yield.

The development of high yielding inbred lines with S-alleles giving high levels of self-incompatibility was continued to facilitate the production of large quantities of F_1 seed by insect pollination and thus to determine whether this level of heterosis is maintained over sites and seasons.

Genetical analyses of heterosis are being concentrated on two of the heterotic crosses identified from earlier work. They form part of a new CASE biometrical genetics project with the Genetics Department of Birmingham University. Inbred lines are being produced from these crosses by single seed descent and by androgenesis [see PU 4(h)].

(J. E. Bradshaw)

Inter-plot competition in yield trials of swede [PU 4(m)]

In the swede breeding programme single-row plots are customarily used to enable replicated yield trials of F_3 families to be grown, despite the large numbers of entries and small quantities of seed available. However, inter-plot competition can bias the results from single-row plots. Analysis was completed of two experiments grown in 1986 to evaluate the use of single-row plots for assessing dry-matter yield.

The first experiment compared the dry-matter yields of 20 cultivars grown in unguarded single-row plots and both unguarded and guarded double-row plots. The correlation between unguarded single-row and guarded double-row plots was poor ($r = 0.39$). It was improved ($r = 0.58$) by adjusting the single-row plot fresh-weight yields for inter-plot competition, through an analysis of covariance in which the covariate was the mean of the adjacent plot yields, and then estimating the pure stand dry-matter yields. However, the improved correlation was still lower than that between unguarded double-row plots and the guarded double-row plots ($r = 0.73$) and this latter correlation was also improved ($r = 0.82$) by adjusting the fresh-weight yields of the unguarded plots for inter-plot competition.

The second experiment in which the individual neighbour effects of six cultivars were determined provided an explanation for the partial success of the covariance adjustment. Doon Major and Ruta Øtofte decreased the yields of adjacent cultivars whereas Dryden and Melfort increased them. Angela and Magres had little effect. The correlation between the dry-matter yield neighbour effects of cultivars and their fresh-weight yields was high ($r = -0.81$), but not complete. So although competitive ability was associated with root fresh-weight yield, other factors must also be involved.

It was concluded that a two-replicate trial with unguarded double-row plots is preferable to a four-replicate trial with unguarded single-row plots for dry-matter yield assessment of early generation families in a pedigree swede breeding programme. For the assessment of potential cultivars guarded double-row plots should continue to be used in order to minimise the effects of competition between neighbouring plots.

(J. E. Bradshaw)

Improvement of leafy brassicas [PU 4(n)]

Rape cultivar breeding

Rape breeding is now focused on the production of materials combining valuable characters presently dispersed among a number of breeding lines, and on introducing to forage rape the low glucosinolate and low erucic acid seed characters of double-low oil seed rape. Of the 86 cross-combinations produced in furtherance of this aim, one third were backcrosses for the introgression of seed characters and most of the remainder were concerned with combining resistance to disease with other agronomic traits.

The candidate cv. Bonar (*Ann. Rep. 1985,* 52; *1986,* 57) completed National List Trial procedures and a decision on acceptance is awaited. It has been shown to have relatively low concentrations of progoitrin in leaves and stems by comparison with other rape cultivars. Grown in trials with MLURI to assess grazing by sheep on an upland site (Harthill Farm) Bonar displayed better tolerance of severe weather conditions than five other UK and New Zealand cultivars.

Yields in trials of F_3 to F_5 generations were relatively low owing to weed competition and low fertility following very wet conditions in June. Selections with yields at best 37% higher at F_3 to 5% higher at F_5 than Emerald, the highest yielding control cultivar (7.05 t/ha), were made from all generations.

Populations in the preliminary experiment grown to provide information on the use of early-generation cross-prediction methods (*Ann. Rep. 1986,* 56) were ranked by the summed scores allocated for fresh yield, dry matter content, yield of dry matter, height, extent of flowering development and proportion of broken petioles. Six populations, representing the upper, median and lower parts of the scale, were grown again the following year and individual plant selections made from each for seed production to continue the experiment. A second experiment grown in 1987 using 24 populations was designed so that within-plot as well as between plot variation could be estimated for the same traits as those in the first experiment. Observation plots of these populations were grown concurrently to provide plants for subsequent seed production.

Experiments to find a rapid measurement of the hardness of rape stems to assist in selecting more palatable forms (*Ann. Rep. 1984,* 57) were extended by using an alternative pattern of load cell in an FTC TP-1 texture press to measure samples. This was combined with additional measurements of the resistance of stems to bending and the area of lignified tissue in stained transverse sections of stem samples. The analysis of results is not yet complete.

(W. H. Macfarlane Smith)

Antinutritional factors in rape breeding

The time-course study of toxic constituents reported in part (*Ann. Rep. 1986,* 152) was completed with estimation of S-methyl cysteine sulphoxide (SMCO) contents which varied from a peak concentration of 0.63g/100g 9 weeks after sowing to 0.28g/100g 18 weeks after sowing. There was little variation between the three genotypes examined or between leaves and stems. Samples were taken on a number of occasions from further experiments grown to provide additional information on the variation in distribution within plants and with time of glucosinolates and SMCO.

(W. H. Macfarlane Smith, D. W. Griffiths[1])

[1]Chemistry Department

Dual purpose cropping of rape

The trial sown in 1986 to assess and compare forage yields, regenerative capacity and potential for seed production in forage and oil seed rapes (*Ann. Rep. 1986,* 57) was carried through to flowering and seed production. Despite considerable seed loss caused by pod shattering and technical difficulties in handling the seed crops the best seed yields in individual treatments of the forage cv. Hobson were equivalent to 2.9 t/ha and in the oil seed cv. Jet Neuf 1.4 t/ha. In a similar trial sown in 1987 Hobson gave forage yields up to 9.27 t/ha dry matter and Jet Neuf 7.86 t/ha 15 weeks after sowing. A larger proportion of plants of Jet Neuf flowered prematurely than in the previous trial, possibly as a consequence of advancing the sowing date a week (to 27 May).

(W. H. Macfarlane Smith)

Kale population improvement and cultivar production

The kale breeding programme consists of two population improvement selection schemes. In one of them the primary emphasis has been placed on selection for improved clubroot resistance (*Ann. Rep. 1985,* 51). The mean disease index of the fourth generation was 0.38, compared with 31.32 for the mean of the control cultivars, Bittern, Canson, Condor, Kestrel and Merlin. More seed of the population was produced during 1987 to enable a more extensive evaluation to be made of its clubroot resistance.

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

Stock multiplication [PU 4(f)]

Seed crops of 66 breeding lines of rape, swede, kale and turnip ranging from F_3 to advanced generations were produced in insect-proof polythene tunnels and a compartmented Dutch light greenhouse. Seed yields of swede were considerably higher than in the previous two seasons, kale yields showed a smaller increase, while those of rape were unchanged (Table 1). Blow-flies were introduced to flowering crops to promote pollination. During this period some infestations of aphids and caterpillars built-up because insecticides could not be applied. Crops were sprayed routinely to control powdery mildew and disease incidence was generally low, except on rape crops after pods began to fill.

Residual variation within breeding lines was strictly controlled to ensure uniformity and stability of advanced selections. However certain forage rape lines which have *B. campestris* ssp. *nipposinica* in their pedigrees displayed very wide, continuous variation, particularly for leaf morphology and frequency and distribution of hairs.

Seed germination tests, undertaken according to International Seed Testing Association rules, showed that two of 15 swede and five of 32 rape seed multiplications did not attain the minimum germination standard.

[1]Mycology and Bacteriology Department

There were no obvious reasons for the low performance of the swede breeding lines but seed dormancy might be involved. By contrast, there had been excessive vegetative vigour in some rapes, associated with secondary vegetative growth and flowering, delay in plant senescence, high humidity and disease incidence and poor seed set.

Satisfactory growth responses and increased seed yields were obtained in an experiment to control the excessive vigour of forage rape by spray application of the growth regulator triapenthenol. Further investigation is required to determine the optimum time of application.

Multiplications were made of 19 of 141 obsolete swede cultivars collected over the past 10 years. Most of these accessions which had either poor germination or few seeds have now been multiplied and samples of each lodged with the Genebank of the IHR (Wellesbourne). An isolated field plot was sown in late October 1986 for multiplication of the new cv. Bonar. Plants established and grew poorly, with symptoms of probable herbicide damage. The plot was re-established in April 1987 with pot-grown transplants but flowering did not occur until late autumn and only a low yield of viable seed was achieved.

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

Table 1. Seed yields

	1987	1986	1985
	mean yields, g/m^2		
swede	147	98	100
rape	114	112	118
kale	84	62	76
	mean yields, g/plant		
swede	103	55	77
rape	42	35	43
kale	36	32	33

Trials of advanced selections [PU 4(f)]

Assessments of breeders' advanced selections of kale, forage rape and swede were carried out in 14 trials at seven sites. All crop yields were affected by above average rainfall.

The mean yields of rape trials differed widely between sites and there were also considerable differences in entry rankings between sites. Similar differences were obtained for dry matter content which was also biased by the very high values for cv. Caron caused by premature flowering. Selection 80035/4 performed most consistently and, overall, gave the highest yield (Table 2). Selection 80195/4 had the highest individual trial yield and a mean yield which was not significantly less than 80035/4, but it performed less consistently between sites.

Kale was grown only at Gourdie farm in two adjacent trials, one of which was irrigated. As conditions after sowing were dry, there was a pronounced initial response to irrigation but the irrigated trial gave a yield only 3.6% higher than the non-irrigated trial as wet conditions prevailed during the remainder of the growing season.

The fourth generation polycross selection PX80/106, which was also in NIAB Vartest trials, again performed well. The mean yield of six fifth generation polycross selections was higher than that of the control cultivars Bittern, Condor and Kestrel.

Among the swede selections in trial only SS8 had a significantly higher yield of dry matter than cv. Angela, the highest yielding control cultivar (Table 3). Four of the remaining eight selections had yields similar to Angela. Powdery mildew was scored at Gourdie Farm only, as infection levels were generally low. Cv. Doon Major was the only markedly infected entry in the trial.

(R. N. Wilson)

Table 2. Rape: means from five sites

Control cultivar	*Fresh yield (t/ha)*	*Dry matter %*	*Dry matter yield (t/ha)*
Emerald	52.73	13.13	6.88
Hobson	51.12	13.09	6.67
Caron	43.03	13.31	5.68
Mean of control cultivars	48.96	13.18	6.41
Breeding selections			
B17	57.52	11.66	6.73
Bonar	59.81	11.22	6.71
80035/4	53.26	13.16	6.98
80195/4	52.98	13.16	6.93
79016/7	55.91	12.09	6.73
Selection mean	55.90	12.26	6.82
Grand mean	53.30	12.60	6.66

Table 3. Swede: means from four sites.

Control Cultivar	*Fresh yield (t/ha)*	*Dry Matter %*	*Dry Matter yield (t/ha)*	*Mildew* (score 1–good 9–bad)*
Angela	95.76	10.95	10.42	1.84
Angus	70.32	13.26	9.29	2.33
Doon Major	87.81	9.97	8.62	6.84
Bangholm Magres	79.28	12.22	9.62	0.17
Marian	85.14	10.99	9.32	1.17
Melfort	76.12	13.21	10.04	2.00
Ruta Øtofte	88.29	11.69	10.23	2.17
Mean of control cultivars	83.25	11.76	9.65	2.36

*Scored at Gourdie Farm only.

Table 3. Swede: means from four sites. *(continued)*

Control Cultivar	*Fresh yield (t/ha)*	*Dry Matter %*	*Dry Matter yield (t/ha)*	*Mildew* (score 1–good 9–bad)*
SS1	77.55	12.34	9.45	0.00
SS2	80.06	12.49	9.96	0.84
SS3	82.91	12.68	10.43	1.17
SS4	69.89	12.71	8.78	1.85
SS6	72.08	13.20	9.45	0.50
SS7	93.14	11.25	10.36	0.67
SS8	97.12	11.15	10.78	0.67
SS9	93.75	11.11	10.36	1.50
SS10	91.52	11.37	10.30	1.00
Selection mean	84.23	12.03	9.99	0.91
Grand mean	83.80	11.91	9.84	1.54

*Scored at Gourdie Farm only.

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

Synthesis of *B. napus* by embryo culture following interspecific pollinations between *B. campestris* and *B. oleracea* is a valuable method of introducing new characters into breeding lines for the improvement of swede and rape. Further crosses were made between the *B. campestris* line (ECD04) which has major gene resistance to *Plasmodiophora brassicae* (clubroot) and *B. oleracea* plants selected for polygenically determined resistance to the pathogen. Sixteen haploid *B. napus* synthetics were obtained from 120 pollinations and were treated with colchicine (1% solution on five successive days) in order to obtain fertile diploids.

Low glucosinolate content is required for all cultivated *B. napus* crops. The cabbage cv. Tastie (*B. oleracea*), which was reported to lack 2-hydroxy but-3-enyl glucosinolate (progoitrin), the predominant glucosinolate in *B. napus*, was used in interspecific pollinations with cv. Hybrid Petit White (*B. campestris*), which also lacks this glucosinolate (*Ann. Rep. 1986*, 60). Damage by aphids severely affected embryo production and it will be necessary to repeat the pollinations.

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

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

Anther culture in swede

Anthers from eight inbred swede lines were cultured in order to obtain homozygous genotypes for genetical research and breeding studies. Microspore embryos were produced by all the lines cultured on the modified Gamborg B5 oil seed rape anther culture medium of Keller *et al.* (1975). Not all lines responded equally: inbreds from cultivars Criffel and

Bangholm Dima produced 3.1 and 2.5 embryoids per plate (18 anthers per plate) as compared to 1.8 from the oil seed rape cv. Tower, included as a control. The highest overall response of 4.0 embryoids per plate was obtained from anthers of inbred line 161RY cultured on the medium of Nitsch and Nitsch modified by Lichter (1982) for isolated microspore culture. The other lines responded poorly to culture on this medium. Only cv. Tower responded favourably to a cold shock pretreatment.

From 9,100 plated anthers, 645 embryos were obtained. All had swollen hypocotyls with fused cotyledons and some showed anthocyanin pigmentation. They were subcultured on to a range of media but normal growth could only be obtained by repeated subculture. Secondary embryogenesis was common during the subculture period and as many as 30 secondary embryoids were subcultured from a single initial embryo. The effect of modifying the subculture media was examined in a subsequent experiment. Embryoids survived well, giving rise to multiple normal shoots on a complex shoot induction medium (Banks, pers. comm.). These shoots gave rise to normal plantlets after transfer to a rooting medium (Murashige and Skoog, 1973).

(J. E. Middlefell Williams)

Ovary culture in the synthesis of B. napus

Experiments confirmed greater efficiency of the technique of culturing ovaries of *B. campestris* from 6 to 10 days after pollination by *B. oleracea* followed by embryo removal and culture, over that of direct culture of embryos from ovaries allowed to develop on the plant. Initially a modified White's medium with further vitamin supplementation and the addition of casein hydrolysate was used for ovary culture. Developing embryos excised from ovaries after 25-30 days in culture were naked and mostly at the late torpedo or walking stick stage of growth. Embryos of the same age developed *in situ* were less mature, being at the globular or heart stage, and were less readily manipulated. In subsequent experiments substituting a Nitsch and Nitsch medium for ovary culture gave increased rates of embryo recovery, yielding one embryo per pollination. Although a larger proportion of embryos showed growth abnormalities on the latter medium, they readily became normal after transfer to a medium modified from Ross (1980).

(J. E. Middlefell Williams)

Regeneration from tissue explants

For genetical research it may be necessary to maintain plants with unique genotypes after they have been seeded in order that further crosses or evaluations can be made. As direct vegetative propagation of senescent plants is sometimes difficult or undesirable, but flower buds or flowers can usually be found, the regeneration of *B. napus*, *B. campestris* and *B. oleracea* from these sources was examined. Excellent regeneration was obtained from immature buds, 2-3 mm long with a pedicel, from whole apical clusters of buds, and from more mature ovaries.

(J. E. Middlefell Williams)

Pollen Selection

The elimination of unwanted genotypes from a pollen population prior to pollination (pollen selection) would markedly increase selection efficiency and be of considerable benefit to plant breeders. Pollen selection was used in an attempt to obtain *B. napus* plants resistant to phytotoxic compounds present in culture filtrates of *Alternaria brassicicola*, the causal organism of grey leaf spot of *Brassica* spp.

The F_1 progenies obtained from crossing the oil seed rape cv. Primor with incubated selected (47 plants) or unselected pollen (52 plants) from cultivars Herkules or Arran (*Ann. Rep. 1986*, 61) were grown in a greenhouse with a similar number of progeny plants from control pollinations. Isoenzyme analyses showed that while most of the progeny from the selected pollen treatment were hybrid, a significant proportion (30%) possessed only maternal isoenzymes and they were presumed to be matromorphs. The effect of the partially purified toxic culture filtrate on the F_1 plants was investigated using a leaf bioassay but no differences were found between progeny from selected, unselected or control pollinations. The germination of pollen from the F_1 in medium containing 0, 10, and 20 mg/ml of the partially purified toxin was also tested. No pollen germinated in the 20 mg/ml concentration but, in 10 mg/ml, pollen germination of eight plants from pollinations using selected pollen was significantly above that of the unselected or control progeny. These plants, together with unselected and control progeny, were self-pollinated in order to examine the resistance to the toxin of F_2 progeny.

(J. R. T. Hodgkin, M. V. MacDonald[1])

In vitro *selection for herbicide resistance*

Additional resistance to herbicides would be valuable in a number of brassica crops and a new IFS programme to use *in vitro* selection to obtain resistance to important selective herbicides such as glyphosate and chlorosulphuron was begun. Protocols for the production and multiplication of tissue from leaf discs and shoots have been investigated and preliminary work on cell culture and the isolation of protoplasts was carried out.

(A. Kumar)

Genetic studies in *Brassica campestris* [PU 4(i)]

The inheritance of 2-hydroxy but-3-enyl glucosinolate (progoitrin) was investigated by intercrossing the turnip cv. Hybrid Petit White, which lacks this compound, with cultivars Bruce and Purple Top White Globe. HPLC analysis showed that the concentration of progoitrin in the F_1 progenies was intermediate between the levels in the parents. F_2 and backcross progenies were grown to provide material for further genetic studies.

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

[1]Department of Botany, Cambridge University
[2]Chemistry Department

Genetic studies in artificial *Brassica napus*[PU 4(i)]

Further studies were carried out on the use of dihaploid artificial *B. napus* as a bridge for the transfer of characters between *B. campestris* and *B. oleracea* (*Ann. Rep. 1986*, 62). Progeny, obtained from self-pollinations of triploid plants (containing one *B. oleracea* genome and two *B. campestris* genomes), were grown and scored for the presence of known *B. oleracea* marker genes. The characters recorded included leaf shape, leaf margin serration, leaf hairiness, the presence of stem anthocyanin, height to first flower, susceptibility to mildew, sepal and petal colour, anther attitude, flower size and acid phosphatase isoenzyme pattern. All the plants tested showed some *B. oleracea* characters and transmission of the characters appeared to be at random. Such material can be used for the production of addition lines and further self-pollinations were made for this purpose.

(J. R. T. Hodgkin)

Self-incompatibility studies [PU 4(j)]

In order to study further the operation of the self-incompatibility system in *Bassica napus*, synthetic *B. napus* plants were produced from intercrosses between three *B. oleracea* lines homozygous for the incompatibility alleles S29, S14 and S2 and two *B. campestris* S-allele homozygotes. A high level of success was obtained, with an average of one dihaploid synthetic per pollination. The hybrid nature of the synthetics was confirmed by isoenzyme electrophoresis. The chromosome complement in a substantial number of the hybrids was doubled by treatment with colchicine. The plants began to flower at the end of the year and will be used to determine the interaction of the *B. campestris* and *B. oleracea* S-loci.

Interspecific incompatibility between *B. napus* pistils and pollen from *B. oleracea* was reported previously (*Ann. Rep. 1986*, 63). During the year its presence was confirmed in three newly synthesised artificial *B. napus* genotypes although one other synthetic was found to be cross-compatible with *B. oleracea*. In the incompatible pollinations pollen tube growth was inhibited at the stigma surface, although germination of the *B. oleracea* pollen was usually extensive with considerable coiling of the pollen tubes. As with self-incompatibility in *Brassica* spp., interspecific incompatibility was overcome by cycloheximide and, usually, by bud pollination.

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

[1]Research Student

POTATO BREEDING

G. R. MACKAY

The 1987 growing season got off to a rather slow start, and although planting was completed by the end of April, the cold wet conditions which followed delayed emergence. Despite this, yields from the ware trials at The Murrays farm and the UK regional centres were good — probably a reflection of the more than adequate rainfall during the growing season. Harvests at both Blythbank and The Murrays farms were completed expeditiously with very few days lost to bad weather. Unfortunately, the average number of tubers was lower than usual, possibly because planting well-sprouted seed into rather wet cold soil had produced fewer stems. Whereas the tuber size compensated for the ware yields, the lack of seed will again probably require the use of a proportion of 'once grown seed' from The Murrays farm in 1988. Seed health was good, and in a year when blackleg and associated disorders have been generally widespread, SCRI-grown stocks have been relatively free of these problems. Unfortunately, the wet summer provided ideal conditions for the development of powdery scab in some Blythbank stocks, partly, at least, in association with a wetter or poorly drained part of the field. This highlights the increasing importance of this disease, which will be exacerbated as irrigation becomes more common in the UK, and it is pleasing to report that some progress has been made in developing a reliable test for this disease. As in other instances, without an effective screen and access to heritable variation, the breeder can make no progress; SCRI experience confirms that there are significant differences in susceptibility between clones, indicative of heritable variation, but there is not yet a proven screen to test progenies from crosses between resistant parents.

Cultivar Glenna (formerly clone 12288 af 12) was placed on the UK National List. It is a high yielding, good quality second early clone, combining H_1 resistance to the golden cyst nematode with a high level of quantitative resistance to the white cyst nematode. It thus offers a marked improvement in PCN resistance over existing second early cultivars.

The Institute and DAFS jointly submitted clone 13737 1 for National List testing in 1987. This clone combines excellent levels of resistance to fungal diseases, particularly late blight, with resistance to the common viruses and a high yield potential of attractive red-eyed tubers. However, the most interesting feature of this clone is that it can be stored at low temperatures for long periods without developing 'low temperature

sweetening'. As a roaster, baker or a chipper for table use, 13737 1 has attracted substantial interest amongst staff who have access to it, and as a processing cultivar its value to the crisp industry could be very substantial.

The 1987 overseas trials were successfully managed and harvested, and selections have been retained for further trialling. Unfortunately, staff shortages and other commitments have delayed the processing and interpretation of much of the data.

Interesting developments continue in the production and use of dihaploids, which are now recognised as a key part of fundamental studies of potato breeding. At the same time, conventional tetraploid breeding is being placed on a sounder scientific base by exploiting progeny tests for various agronomic and disease resistance traits. This provides improved germplasm as well as the means by which the products of genetic engineering and of conventional breeding can be compared.

The Birmingham collection of wild species of potato was sent to DAFS ASS, East Craigs, and discussion continued as to how to finance its amalgamation with the Commonwealth Potato Collection.

The Department recently has obtained an IBM PS Model 60 micro computer. This has 1Mbyte of RAM, 44Mbytes of hard disc storage and a 3.25 inch disc drive. All the department-poduced software, including the latest version of the Computer Housed Information Package, is being converted and mounted on to this computer.

Crisping quality after low temperature storage [PU 1(a)]

Routine fry tests of clones from the potato breeding programme consistently identify a small proportion of clones which give superior (paler coloured) crisps than the control cv. Record, after storage at low temperature (4°C). Thirteen such clones and nine cultivars were subjected to a more thorough trial in which they were fry tested direct from storage at 4 and 10°C for varying lengths of time. The ability of some of these clones to produce an acceptable fry product direct from storage at low temperature, and their superiority in this respect over existing cultivars, was confirmed. Five clones still produced crisps with an acceptable fry colour after 30 weeks storage at 4°C.

A high reducing sugar content is primarily responsible for the development of the undesirable dark brown colour of crisps. Therefore, at each fry date a sample from each clone was freeze dried and the percentage of sucrose, glucose and fructose per unit dry weight was estimated by the Chemistry Department. A high correlation was obtained between glucose and fry colour ($r = -0.08$, $P<0.001$) and between fructose and fry colour ($r = -0.6$, $P<0.001$). Forward stepwise multiple regression of both sugars on fry colour showed that glucose was the more important in determining crisp colour. Adding fructose to the regression equation hardly improved the precision of the prediction. One of the clones (13737 1), which produced

crisps of acceptable colour throughout the trial from tubers stored at 4°C, had low initial levels of both glucose and sucrose and also showed a low accumulation of sugars after storage. It has now been submitted for NLT.

An experiment is under way to provide information about the inheritance of fry colour at harvest and after low temperature storage, and of sugar accumulation during low temperature storage. Hybrids and selfs from an eight x eight half diallel hybridisation programme were obtained in 1986. The eight parents were chosen to represent the range of crisp colour and sugar content confirmed in the trial detailed above. Only four of the possible 36 crosses failed to produce seed. In 1987, seed samples from each cross were sown and four samples of 14 seedling subsequently transplanted into 13cm square pots. The samples were randomised and grown in an aphid-proof glasshouse. Seven stem cuttings from each of the eight parents were included in each sample block. The whole experiment therefore consisted of 1792 seedlings (four samples of 14 seedlings from each of 32 crosses) and 224 stem cuttings (four samples of seven stem cuttings from each parent).

Immediately after harvest, a single tuber from each plant was fry tested and the crisp colour assessed visually. In mid-December after 6 weeks storage at 4°C a second tuber was fry tested. A third test will be carried out early in 1988, and at the same time a sample of tubers from each cross will be freeze-dried to provide material for sugar analysis. Each seedling was individually identified, and hence crisp colour from the three assessments can be traced to a single plant. When the trial is completed, it should be possible to determine the efficiency of selection for crisping quality on individual seedlings or on a progeny basis.

(J. Brown)

Introgression of late blight resistance from wild species [PU 1(a)(g)]

In 1986, 68 accessions from the Commonwealth Potato Collection were sown and the seedlings sprayed with a spore suspension of a complex race of *Phytophthora infestans*. Seedlings which remained uninfected were grown to maturity in 10 cm pots. The accessions included the diploid species *Solanum microdontum, S. verrucosum, S. hjertingii, S. polyadenium, S. vernei, S. berthaultii* and *S. pinnatissectum;* the tetraploid species *S. papita* and the hexaploid species *S. demissum*. Resistant survivors were obtained from all species except *S. berthaultii* and *S. hjertingii*. Attempts were made to hybridise those seedlings which flowered with dihaploid clones (in the case of the diploid and hexaploid species) and with *S. tuberosum* cultivars and clones (in the case of *S. papita*). Many pollinations were carried out, but seed was secured from only a very low frequency of crosses involving *S. vernei, S. papita* and *S. demissum*.

In 1987 potted plants grown from tubers of resistant seedlings were reinoculated and those giving a hypersensitive response were discarded to

eliminate genotypes whose resistance might be due to a major gene. Resistant clones which showed no hypersensitive reaction were planted for crossing. Seed set was much better than in 1986, probably because plants grown from tubers were stronger than those from true seed. Seeds from the F_1 hybrids produced in 1986 were sown and the seedlings tested for resistance. The survivors were retained and backcrossed to either dihaploids or tetraploids of *S. tuberosum*, depending on their likely ploidy levels. The intention is to repeat the back crossing until the resistance genes are transferred into a more agronomically suitable genetic backgroud.

Several resistant diploid survivors from the first seedling screen have been retained for use in protoplast fusion studies. Another aim of this introgression study is to combine potato cyst nematode resistance with blight resistance by hybridising *S. demissum* (hexaploid) with *S. vernei* (diploid, with good nematode resistance). If the hybrids obtained in 1987 prove to be tetraploid, as expected, it may be possible to hybridise them immediately with *S. tuberosum* clones and cultivars.

(J. Brown, H. E. Stewart)

Regional trials of advanced selections [PU 1(a)]

All clones in the sixth clonal generation of selection and beyond were grown as usual in trials at ten sites throughout the UK (*Ann. Rep. 1986*, 66) in order to expose them to a wide range of agricultural conditions. Yields in 1987 were generally good.

On the basis of their performance in these and previous years' trials, the results of routine disease and pest resistance tests and assessment of their quality characteristics, several clones were identified as potential NLT candidates and will be retrialled in 1988. Two clones were considered for NLT submission this year. One, 12721 ae 14, which in addition to its UK potential has also demonstrated seed export potential during trialling in Mediterranean countries, will be re-trialled overseas during 1988, but the other, 13737 1, has been submitted for NLT. This high yielding early maincrop clone produces an attractive sample of white-skinned oval tubers with shallow red eyes. It has an excellent spectrum of resistance to the common fungal and viral pathogens. Its cooking qualities are good and it appears equally suitable for chips, roast and baked potatoes. Its potential as a processing cultivar is extremely high, as it can be stored at low temperature for long periods without exhibiting low temperature sweetening, and it produces fry products consistently superior to those of cv. Record.

(M. F. B. Dale)

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

More than 60 clones and control cultivars featured in the routine overseas agronomic assessment trials in 1987. These included forty-nine sixth clonal generation (M4) clones which were trialled for the first time in Spain (two

sites), Cyprus and Israel, and eight advanced clones which had performed well in previous trials. On the basis of their performance over several years in the UK and overseas, clones G7707 2, 13121 ab2 and 12721 ae 14 have been identified as potential cultivars. They will be retrialled at all sites in 1988 and an Approved Stock produced with a view to NLT submission.

Four other advanced clones were selected for further trials in the UK and overseas in 1988. Two advanced clones continue to show promise as having seed-export potential, although they are of only moderate yield in the UK. They will be trialled once more overseas by SCRI, and in addition seed tubers have been supplied to commercial collaborators in Cyprus, Israel and Spain, who will make an independent assessment of their capabilities. Of the two, clone 12719 ae 4 has been of particular interest in Cyprus, and 12492 ad 6 in Algeria, where it has performed exceptionally well over two seasons. Unfortunately, seed supplied for trial in Algeria in 1987 was lost in transit. Clone 12492 ad 6 is extremely resistant to late blight in the foliage, an attribute which appears to be common among clones with export potential. Chemical control of late blight is difficult and not always successful under the conditions of heavy disease pressure which prevail in countries such as Algeria. Resistance to late blight is likely to confer a greater yield advantage in such environments than in the UK.

The collaborative project with the Israel Agricultural Research Organisation at Gilat in the Negev continued. In addition to agronomic evaluation, clones and control cultivars were again exposed to infection by *Verticillium* and *Alternaria*. The Fall (autumn) data are not yet available, but preliminary analysis of data from the spring trials presents a broadly similar picture to previous years, and the resistance or tolerance of several SCRI clones to these important diseases was confirmed.

Rainfall is the limiting factor in practically all the important Mediterranean and North African potato growing areas, and some form of irrigation is necessary. Many of these areas, including Israel, are experiencing difficulty matching water supply with demand. Irrigation with brackish (saline) water, which is often plentiful, has tremendous potential if suitable cultivars can be found. Israeli irrigation experts have developed sophisticated control systems in which intermittent flushes of sweet water greatly ameliorate some of the problems of using saline water, and make it possible to grow potatoes with saline water as the main water source. Unfortunately, saline water exacerbates *Alternaria* and *Verticillium* as well as depressing yield *per se*.

For the first time in 1987, some SCRI clones and several cultivars whose resistance or tolerance to *Verticillium* and *Alternaria* had been assessed in previous trials, were grown under a saline gradient at Gilat. This enabled them to be subjected to a range of salt concentrations in the irrigation water, by planting the trial between parallel spray lines delivering either saline or fresh water. Preliminary analysis of the data indicated that clones

or cultivars tend to rank similarly for yield under both saline and fresh water regimes when diseases are controlled. However, disease expression is more marked under saline conditions and this causes a greater yield loss. Thus resistant cultivars will be desirable if saline water is more widely applied.

Following an initiative by the Scottish Seed Potato Development Council to strengthen links between the public agricultural R. & D. sector and Portugal, an important export market, SCRI was invited to submit a few advanced clones for trial at Vila Real. Six clones of export potential and two control cultivars were dispatched in Spring and the trial harvested in September. Useful contact was made with researchers of the Universidad de Tras-os-Montes e Alto Douro, who grew the trial. Clones 13121 ab2 and 12721 ae14 outyielded cv. Désirée, the highest yielding control. The Vila Real site is new to SCRI, and it is gratifying that two of the six clones performed so well. Both are maincrop, and earlier maturity material had senesced some weeks before harvest. Consequently only maincrop clones will be supplied to Vila Real in future. SSPDC have identified another site in the early potato growing area of Portugal, to be managed by the co-operative UCANORTE, to whom seed tubers of four early clones and two control cultivars have been supplied for 1988.

By the end of December, seed tubers for Valencia (Spain), Cyprus, Israel and the Portuguese early site had been inspected and dispatched.

(G. R. Mackay)

Assessment of drought tolerance in potatoes [PU 1(b)]

Increased efforts have been made to develop tests to assess drought tolerance which is particularly important in the arid growing conditions of North Africa, for example, where lack of water is the limiting factor. Currently there are no reliable tests to assess drought tolerance suitable for large numbers of clones.

Attempts at screening for drought tolerance by growing cultivars in the field under a polythene cover to exclude water proved unsuccessful. During 1986 and 1987 22 cultivars of different maturities were grown in a replicated trial in a glasshouse in 23 cm and 13 cm pots. At the onset of flowering half the plots were deprived of water for 22 days. Severe wilting was observed, more so in some cultivars than others. At maturity, the yield and number of tubers per pot was recorded. These data are currently being analysed.

(M. F. B. Dale)

Potato cyst nematode (PCN) resistance and tolerance [PU 1(a)(e)]

Field tolerance trials continued with ADAS and PBI (*Ann. Rep. 1985*, 64), in which the yields of nematicide treated plots were comparedwith those of untreated plots. Analyses of the data from the previous 4 years have shown significant differences in PCN tolerance between the clones. However, there were also significant interactions between clones, sites and years,

indicating that the clones did not behave consistently between sites and years. This implies the need to trial such material at more than one site and in more than one year in order to identify the most tolerant clones.

Analyses of the data also indicated that the clones differed significantly in the rates at which nematodes multiplied on their roots. Although these multiplication rates varied from site to site, the relative differences between the clones were maintained across sites. Under the susceptible control cultivars the populations generally increased, even in the presence of nematicide. The partially resistant clones tended to exert good control at sites with higher initial population densities, and in conjunction with nematicide gave good control at all sites irrespective of the initial population density.

It is now evident that no correlation exists between resistance and tolerance to PCN, thus confirming the importance of such trials.

(M. F. B. Dale)

Early generation selection [PU 1(c)]

Clonal selection in the seedling stage has now been abandoned in the light of recent research (*Ann. Rep. 1986*, 69). Progeny trials are carried out to select superior progenies on the basis of univariate cross prediction of breeders' preference (a visual assessment of seedling-produced tubers to determine their commercial worth). These predictions are then used, along with predictions based on the resistance of the progenies to foliage blight, tuber blight and potato cyst nematode (*Globodera pallida*), to identify the superior crosses. Larger quantities of these are then sown and the tubers multiplied at Blythbank without selection until they can be assessed at the second clonal year. Until 1987, such cross prediction had only been attempted on *Solanum tuberosum* x *S. tuberosum* progenies. In 1987, a glasshouse grown seedling progeny trial which included crosses of Neo-Tuberosum x *S. tuberosum* (plus reciprocals), Neo-Tuberosum x Neo-Tuberosum, and *S. tuberosum* x *S. tuberosum* was assessed. Progeny clones from this trial will be assessed in the field to determine the utility of such cross prediction methods on a wider range of crossing types.

Cross prediction at present necessitates hybridising chosen parents and evaluating a sample of the progeny from each cross to estimate the parameters which form the basis of the predictions. It would be very much easier if potentially superior cross combinations could be identified without actually making the cross. An experiment was carried out to examine the merits of cross prediction based on parental performance for tuber characters. Predictions based on the simplest genetic model, i.e. that of mid-parent values with assumed complete additivity of gene action, were found to provide a reasonable estimate of the performance of individual hybrids. Evaluation of mid-self values (based on the performance of some selfs from each parent) provided a more accurate prediction, although not

significantly so. The evaluation of selfs was naturally more labour-intensive and time-consuming than simply evaluating the parents. Neither mid-parents nor mid-selfs provided better predictions than evaluations of some seedlings from each cross. Parental evaluation does, however, permit the elimination of the poorest parents or hybrid combinations from a breeding programme.

(J. Brown)

Breeding material developed from primitive and novel germplasm [PU 1(d)]

Neo-Tuberosum

The Neo-Tuberosum programme has been outlined (*Ann. Rep. 1981*, 181). The following comments update that information on tetraploid material and place the work in an international context.

N. W. Simmonds, who initiated the programme at John Innes Institute in 1961 and brought it to Pentlandfield in 1967, in 1962* expounded his concept of the 'genetic base' of a crop — the gene-pool contained in cultivars and breeding material adapted to the local environment, ready for immediate use in cultivar breeding. He proposed the expansion of genetic bases by selecting for adaptation in populations based on exotic, ill-adapted material. This stimulated 'base broadening' or 'germplasm enhancement' activities with many crops.

R. L. Plaisted commenced a programme at Cornell University, New York, USA, in 1965, using material both from the British programme and direct from South America, supplemented in 1967 with further British material. After some years of selection his population traced to only a few parents, almost all British. Some 1000 further Adigena accessions were therefore crossed with the improved population, the progeny again being crossed with the improved population; selection then continued in this expanded, though largely British-based, population.

T. R. Tarn at New Brunswick, Canada, established a programme using seed supplied from the 1968 and 1969 plots of the British programme. B. Maris at the SVP, Wageningen, The Netherlands, commenced an independent programme in 1967 based on 28 Andigena accessions. Further programmes have recently been initiated in the USSR and West Germany using material from existing populations.

Breeding methods differed between the four well-established programmes, involving open pollination, manual crossing using pollen collected in bulk, or fully controlled breeding between selected clones; selection methods and criteria also varied. Substantial improvements were achieved in all cases, giving rise to populations which are now significant components of

*(Simmonds, N. W., 1962. Variability in crop plants: its use and conservation. *Biological Reviews* **37**, 422-465.)

the genetic base of temperate region potatoes. The expanded genetic base seems likely to contain many genes needed to meet future problems or requirements, enabling them to be dealt with expeditiously. Resistance to many potato diseases, including all those currently of importance in Britain, has been detected in Neo-Tuberosum.

Experiments in all four programmes have shown that hybrid progenies from crossing with Tuberosum (i.e. cultivars and breeding lines developed from them) are high yielding, and usually higher yielding, with fewer berries, when the Tuberosum parent is the female. Variation in yield is at least as great in hybrid as in Tuberosum progenies and, in experiments, most of the highest yielding individual clones are from hybrid progenies.

Neo-Tuberosum was crossed with Tuberosum in the SCRI cultivar-breeding programme in 1969 and in 1974. Progenies from 1969 pollinations had higher discard rates than accompanying Tuberosum progenies, but those from 1974 pollinations, involving more advanced Neo-Tuberosum parents, were as good as Tuberosum progenies. Cv. Shelagh was selected from that batch. Neo-Tuberosum was again used in commercially-orientated crossing in 1986.

About 10% of the progenies raised in the New York cultivar-breeding programme are hybrids between Tuberosum and Neo-Tuberosum, and c. 20% are first backcrosses, (TxN)xT. Discard rates in recent first backcross progenies are lower than in Tuberosum progenies. First backcross progenies in the Canadian programme also look very promising. The SVP does not breed cultivars but selections from B. Maris's programme have been supplied to Dutch commercial breeders.

Material from the British programme is in use in New Zealand, The Netherlands, Turkey, the USA (North Dakota), Canada (St John's, Newfoundland) and elsewhere. Material from the New York programme supplied to the International Potato Centre (CIP) in Peru has given rise to cultivars bred for earliness and heat tolerance released in Rwanda (1), Burundi (2) and Turkey (2); others are near to release in many countries. Neo-Tuberosum parents have also been used at CIP in breeding for resistance to early blight, late blight and virus Y and related viruses, and in the True Potato Seed (TPS) programme.

Current work at SCRI is based on about 200 selections taken from the main population in the 1960s and 1970s. About 1500 clones are in hand but many, from recent controlled breeding for virus, blight, *Verticillium* or PCN resistance or for crisping quality, are still under selection. The aim is to retain a pool of clones representing all 200 'primary' selections, ready for screening if new problems arise, and of sufficiently high agronomic standards to be acceptable as parents for cultivar breeding. The main population, stored as true seed, remains in reserve.

(D. R. Glendinning)

Potato dihaploids

Experiments were carried out on the production of callus from leaf discs in *in vitro* culture and on the regeneration of plants from callus. Of 31 dihaploids 24 produced callus, and seven of these produced plantlets. Genotype had a large effect on callus production and plant regeneration. One dihaploid in particular, PDH727, produced hundreds of plantlets from each callus, whereas most clones produced less than 10. Sixty of the PDH727-derived plants were transferred into small pots containing compost, and chromosome numbers were counted in preparations of root-tip mitotic cells. To date, the ploidy numbers of 22 of these have been checked and all have been found to be tetraploid.

Twenty-two dihaploids have been produced from a somatically chromosome-doubled derivative of the cv. Pentland Crown dihaploid PDH40. As expected, they all closely resembled PDH40 in their foliage and flowers. However, all tended to have a large number of small tubers, unlike PDH40. Analysis of the tuber proteins of 10 Pentland Crown dihaploids at the Paisley College of Technology showed that four of them possessed forms of the major tuber storage protein patatin not found in Pentland Crown. PDH40 had the patatin which was most dissimilar electrophoretically to that of its parent, and this form was also found in its chromosome-doubled derivative and in all 14 dihaploids derived from it which were tested. This illustrates how dihaploids can be used to expose genetic variation which exists in tetraploid potatoes, and can fix characters by increasing homozygosity. In potato dihaploids male sterility and self incompatibility prevent selfing, but progression to homozygosity can take place using repeated cycles of chromosome doubling and rehaploidisation, as indicated above.

Tests were carried out on tetraploids produced by hybridising cultivars with two dihaploids which have high levels of quantitative resistance to both foliage blight (*Phytophthora infestans*) and PCN (*Globodera pallida*). One dihaploid produced nine out of 19 tetraploid offspring with levels of both resistances similar to its own; the other only one out of 15. Clearly there are differences in the breeding value of these two dihaploids, even though both have similar phenotypes for pathogen resistance and produce unreduced (2x) gametes. This could be due to differences in their resistance genes, in their modes of unreduced gamete formation or a combination of both.

Two other dihaploids (PHD417 and 505), obtained from tetraploid hybrids between Group Tuberosum and Group Vernei clones, were completely resistant to PCN (*G. rostochiensis*) and were therefore assumed to possess the dominant major resistance gene H_1. However, the results of resistance tests on the progenies obtained by crossing them with a susceptible diploid (Group Phureja) clone indicated that PDH505 was heterozygous at the H_1 locus (i.e. 1 resistant: 1 susceptible). A more

complex genetic control of resistance, probably involving genes at more than one locus, was indicated for PDH417. The results show that high resistance to *G. rostochiensis* can be determined by genes other than H_1, and that progeny testing is necessary to distinguish between the major gene and alternative genetic systems governing PCN resistance.

(M. J. De Maine)

Diploid potatoes

The field evaluation and selection of tetraploid hybrid material based on improved clones of group Phureja-Stenotomum is carried out in two stages. In the first, hybrid clones are grown as three-plant plots (x two replicates) at wide spacing for three seasons, using cultivars Pentland Crown and Record for comparison. Those experimental clones which show consistent performance for a range of agronomic characters go on to the second stage, where they are compared with five leading cultivars in randomised trials which simulate agricultural practice. Over a number of seasons these randomised trials have shown that the hybrids as a group significantly exceed the Tuberosum cultivars in both total and saleable yields. Since 1985, Tuberosum-Phureja hybrids have been entered in the third clonal generation (the M1) of the cultivar selection programme to compare their performance directly with that of contemporary material generated from other breeding programmes. The 1985 entries were mainly first-generation, 4x hybrids (49), of which seven were selected for retrial in 1986. Of the seven clones, three survived this second round of selection and were included in the fifth generation trials (M3) in 1987. The parents of the hybrids submitted in 1985 included seven different cultivars and seven elite Phureja clones. A number of higher-yielding 2x hybrids (13) was included in that M1 trial for comparison, but none were selected. In most cases, this was due to smaller average tuber weights and more irregular shapes, in comparison to tetraploid potatoes.

Over 50% of the tetraploid hybrid clones submitted for M1 trials in 1986 and 1987 have been of generations beyond F_1. Some have come from intercrossing F_1 hybrids of diverse parentage, but most are back-crosses to Tuberosum cultivars. The commercial selectability of back-crossed material could be higher than that of first-generation hybrids; of five clones, selected in 1986 for inclusion in the M2 trial in 1987, only one was an F_1 hybrid.

Continuing breeding work with improved diploid Phureja permits the selection of parents for inter-ploidy crossing which combines better yields and increased tuber dormancy with resistance to potato leafroll virus and potato virus Y: such a parent is DG207(35), which has been crossed successfully with cultivars Pentland Crown, Pentland Squire and Cara.

The nature of PVY resistance in Phureja selections and in hybrids derived from Phureja has been the subject of field trials and testcrosses.

Polygenic resistance to PVY has been confirmed in the Phureja clone DB176(14) and in two tetraploid hybrids, 2AP2(27) and (56). The other tetraploids have major gene resistance.

(C. P. Carroll)

Tobacco rattle virus (TRV) resistance [PU 1(e)]

The glasshouse test for TRV sensitivity developed at SCRI (*Ann. Rep. 1986*, 77) was used to assess 140 clones from the fifth and sixth clonal years of the breeding programme. The test performed well, allowing the identification of TRV-sensitive clones. A field trial at Tayport was also used to confirm TRV sensitivity or insensitivity in 49 clones from the sixth clonal year.

Data from the 14 progenies screened in 1986 (*Ann. Rep. 1986*, 71) were analysed, and significant heritable differences between the progenies in their TRV sensitivity were observed. The results suggest that there is a single major gene for TRV insensitivity, although this does not explain all the observed variation. It is evident that there is also a polygenic system which can confer good levels of insensitivity to TRV.

The glasshouse test referred to above involves collecting and testing large quantities of soil from an infested site. To investigate a possible alternative method for screening for TRV sensitivity, the developing tubers of 14 pot-grown plants of each of 12 cultivars were jet-inoculated *in situ* with TRV, using *Nicotiana clevelandii* leaf sap infected with TRV strain PRN, diluted tenfold with distilled water. Tubers on an equal number of control plants were inoculated with distilled water. After harvest the tubers were sliced and examined, but no TRV spraing symptoms were observed.

(M. F. B. Dale, R. M. Solomon, J. S. Muir)

Resistance screening [PU 1(e)]

Virus diseases

Potato clones were screened for resistance to potato virus X (PVX) (common and B strains) and potato virus Y (PVY) (common, A, C and a VN strain) by glasshouse methods, for field resistance to PVY (common strain) and potato leaf roll virus (PLRV) in an exposure trial at the IPSR (Cambridge Laboratory), and for their response to tobacco rattle virus and potato mop-top virus in field trials at Tayport, Fife and Braco, Perthshire.

Jet-inoculation of stems using a Panjet inoculator was investigated as a possible alternative to grafting, as a method of artificially infecting potato plants with PLRV. The inoculum was stem and leaf sap from PLRV-infected potato plants of the clone 10527 ab20, used undiluated, diluted x 3 and diluted x 10 with water. Nine plants of each of the cultivars Désirée, Majestic and Pentland Crown were inoculated, but none became infected.

Progeny tests for major-gene resistance to PVY or PVX were done by spray-inoculating seedlings. After earlier progeny tests, clones identified as duplex for PVY resistance were selfed and intercrossed within groups of broadly similar provenance to produce triplex or quadruplex clones whose progenies would comprise only resistant individuals. Clones of the progenies of these duplex x duplex crosses were test-crossed with susceptible parents to identify those that are triplex or quadruplex. Six clones identified as possibly triplex or quadruplex in 1985 were progeny tested again in 1987 but found to be duplex, apparently with a second locus involved. Other clones were progeny tested for the first time in 1987. One of these (G8776(20)) does appear to be at least triplex, giving no susceptible segregants in 40-seedling samples of two progenies. This clone was also found to be simplex for its PVX resistance gene. Seven others gave fewer PVY-susceptible segregants than expected if they were duplex at a single locus, providing further evidence that more than one gene may be involved.

Seedlings of other progenies were routinely selected for resistance to both PVY and PVX by spray-inoculation to eliminate susceptible individuals. Tubers of the resistant survivors will be grown on for further selection for other attributes.

Some cultivars were compared for their suitability for use as susceptible parents in progeny tests for PVY resistance. Plants of nine susceptible cultivars were sap-inoculated with PVY, and their response observed. Two of these cultivars were also selfed, and their seedling progenies screened by spray-inoculation with PVY. Mottled (infected) seedlings were counted and discarded, and the apparently healthy survivors grown on, to check whether they were infected without symptoms, or were susceptible escapes, or resistant. Désirée was also included in this study to find out how it responds to inoculations and how its progenies segregate, because it has only incomplete resistance to PVY: Désirée scores 7 on the NIAB 1-9 scale of increasing resistance (NIAB Recommended List of Potato Varieties, 1987). If this were polygenic and not major gene resistance, and hence not expressed in response to sap inoculation, Désirée could be used as a susceptible parent in test crosses. However, the results of this study suggest that it is simplex for a major gene conferring resistance similar to that found in Pentland Crown.

The nine susceptible cultivars referred to above differed in the severity and duration of mottle symptoms, and most of them also showed necrosis in some plants. Cultivars Conference, Pentland Squire and Maris Peer showed no symptoms in some infected plants; Maris Piper showed strong mottle symptoms, Champion and Arran Peak showed mottles which faded out in older plants, and Dr. McIntosh showed only slight mottle symptoms.

Almost half of the progeny of Arran Peak selfed was not infected and showed only local necrosis when re-inoculated after growing on. The

segregation ratio did not suggest a major gene, but did suggest that Arran Peak is not the ideal susceptible test-cross parent. In the progeny of Dr. McIntosh selfed only one-fifth of the seedlings remained healthy, none showed necrosis and the mottles were the easiest to see out of the three progenies. All the survivors proved to be susceptible escapes when grown on and re-inoculated.

The results indicate that some PVY-susceptible cultivars are better susceptible test-cross parents than others, that the response of a cultivar to sap-inoculation is not an infallible guide to its performance as a test-cross parent, and that some susceptible escapes can be expected. However, Dr. McIntosh is a good susceptible parent for use in test crosses for PVY resistance.

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

Fungal and bacterial diseases

Further work was done to develop a glasshouse test for resistance to *Alternaria solani* (*Ann. Rep. 1986,* 72), and 14 of the clones and cultivars being exposed to the disease in the trial of advanced clones in Israel were assessed in a glasshouse. Potted plants at flowering were sprayed with spore suspension (3×10^3 spores per ml) in a closed cabinet and transferred to a glasshouse 24 h later. Glasshouse and field results generally agreed well ($r = 0.85$, $r_s = 0.86$, $P<0.001$). Plants of nine cultivars were inoculated at different stages of growth: pre-flowering, in bud, and post-flowering. Symptoms developed more quickly in plants which had finished flowering, but assessments agreed with field results equally well at all plant ages. Heating the cabinet to 25°C before inoculation increased infection.

Routine tests for resistance to late blight were again carried out in a glasshouse. Two hundred and one progenies were screened against foliage blight, and 58 of them for resistance to tuber blight as well. A correlation coefficient of 0.68 ($P<0.001$) was observed between the two scores. Clones from the sixth year of selection onwards were assessed in the field trial at Yonderton Farm, Ayrshire.

The effect of spore concentration on the expression of major gene resistance to races of *Phytophthora infestans,* using detached leaflets of members of the differential series, was confirmed (*Ann. Rep. 1986,* 73). Races were more easily identified if spores were applied to each leaflet in a single drop, rather than as a covering of fine droplets from a hand sprayer.

Forty-six clones and cultivars were screened in the joint SCRI/NSCA powdery scab field trial near Portsoy, Banff. Disease pressure was severe, and only nine of the clones/cultivars were of similar resistance to the resistant Ulster Lancer. This scored 8 on a 1-9 scale of increasing resistance, whereas Pentland Crown and Estima scored 3 and 2.5 respectively.

Seedlings from a half-diallel hybridisation of nine parents differing in susceptibility to powdery scab were planted in a progeny trial in brick-sided outdoor beds at Pentlandfield. The soil in the beds had previously been

inoculated with dried skin peelings from a heavily-infected stock of cv. Golden Wonder from Aberdeenshire. The mean incidence of infected tubers in the 15 tested progenies was related to the mean resistance of the parents. The three most resistant progenies were derived from Ulster Lancer.

The Erwinia inoculation trial at Gilat Regional Experiment Station, Israel, was repeated (*Ann. Rep. 1986*, 74). The incidence of blackleg in May was again lowest in cultivars Maris Piper, Pentland Squire, Pentland Crown and Désirée, and highest in the early cultivars Maris Bard, Pentland Javelin and Ulster Sceptre. Other cultivars which were susceptible in 1986 were relatively less so in 1987. There was again no relationship between symptom expression (May) and yield loss (June). Fourteen of the 18 cultivars in the Gilat trial were also inoculated with *Erwinia carotorova* subsp. *atroseptica* (Eca) and planted in Valencia, Spain, in a collaborative trial with L. Matutano S.A. Blackleg symptoms only appeared in plots planted with cut seed tubers, although yield loss was also apparent, and at a similar level, in plots planted with whole tubers. Pentland Crown and Cara suffered little loss of yield in either Israel or Spain, whereas at both sites cv. Ulster Sceptre and Estima were among the most sensitive cultivars. Désirée suffered a greater yield loss in Israel than in Spain.

In a glasshouse pot test at Pentlandfield, vacuum-inoculating tubers of cultivars Ailsa (resistant) and Moira (susceptible) with Eca markedly reduced the number of stems and height of the resulting plants of both cultivars, especially if the seed was not cut before it was planted. No blackleg stem symptoms developed, and the test appears to have been more a measure of the effects of soft rot on the mother tuber than of the occurrence of blackleg.

A blackleg field trial at Pentlandfield confirmed last year's finding (*Ann. Rep. 1986*, 74) that vacuum-infiltration with Eca after harvest gave the highest expression of blackleg symptoms when tubers were planted the following year. Symptoms were also observed on plants from seed tubers vacuum-infiltrated in early March while still dormant, but not on tubers inoculated in early May, whether or not they had been allowed to sprout beforehand. Inoculation by jet injection in May did produce blackleg symptoms, but only in the most susceptible cultivars. This failure of pre-planting inoculation may explain the low level of blackleg observed in clone trials in the last 2 years.

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

Tolerance to late blight

Eighty clones were grown in three trials in a field at Yonderton Farm, Ayrshire, to investigate further the effect of late blight infection on yield (*Ann. Rep. 1986*, 73). All clones were represented by two plots in each trial, in randomised block designs. One trial was inoculated and blight

allowed to develop, while the second was sprayed at intervals with metalaxyl + mancozeb to prevent infection. The third trial was harvested in July before blight symptoms were observed, while the other two were harvested in mid-September when the epidemic in the blighted plot was over. Averaged over all clones in the trials, the early harvest produced 1.02 kg/plant, the blighted plots 1.74 kg/plant, whilst the fungicide-treated plots gave the highest yield (3.07 kg/plant). On average, therefore, there was a considerable yield reduction due to blight infection. Several clones were very susceptible to late blight (as assessed by symptoms on the foliage) but did not show a large yield reduction compared with the control plots. Conversely, some clones were very resistant in the foliage but showed a marked reduction in yield. The aim of the early harvest was to determine the contribution of early bulking to blight tolerance. Although the data are not yet analysed, initial indications are that the susceptible, but tolerant, clones had produced the bulk of their yield before blight appeared.

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

NEW POTATO CULTIVAR

GLENNA*

National List and Plant Variety Rights — 1987

Origin:	10223 7 x 10300 13. *Year of Cross:* 1975.	
Maturity class	Second early, similar to cv. Wilja.	
Foliage	Medium height, bushy; leaves fairly open, mid green, rather harsh; numerous flowers, light blue petals.	
Tubers	Round/oval, regular and uniform shape with shallow eyes; white skin, cream flesh.	
Cooking quality	Good. Firm texture, medium to low dry matter, free from discolouration.	
Processing	Its medium to low dry matter and tendency to produce darker fry products than cv. Record suggest it is of limited use for processing.	
Yield	Mature yield potential is high and as a second early is comparable to cv. Wilja at an immature harvest.	
Disease resistance†	Wart	Field immune to the common European race 1
	Late blight — foliage	5
	tuber	5
	Gangrene	3

*Ownership of the cv. Glenna, for which National List status and Plant Variety Rights were awarded in 1987, was transferred to the NSDO as part of the agreement for its privatisation.
†Numerical scores on 1-9 scale, 9 = maximum resistance or hypersensitivity.

Dry rot	5
Skin spot	5
Common scab	4
Potato cyst nematode:	
Globodera rostochiensis	9
G. pallida	Resistant (see summary)
Virus x	9
Y	5
A	Susceptible
Leafroll	5

Summary

A high yielding, good table quality second early clone combining the qualitative resistance to *G. rostochiensis* of the H_1 gene, from Andigena, with a high level of quantitative resistance to *G. pallida* from *Solanum vernei*. Glenna has also exhibited substantial tolerance to PCN in the absence of nematicide in the SCRI/ADAS field trials. Selected mainly on the basis of its potential as a cultivar for the UK ware market, Glenna has also performed reasonably well in SCRI trials in the Mediterranean area, and may have some export potential to early growing areas in that region.

SOFT FRUIT BREEDING

D. L. JENNINGS

This year we report the release of the black currant cv. Ben Alder, the strawberry cv. Rhapsody, the blackberry cv. Loch Ness and a purple raspberry, and mention two other black currants and a red raspberry as probable releases in the near future. At the same time we describe our first studies on the use of *Agrobacterium* species as vectors for the introduction of new DNA into these crops. This illustrates our aim to produce superior cultivars by conventional methods supported by the most modern techniques available.

We also report progress in studies of the nature and inheritance of characteristics relevant to the breeding objectives. These include studies of the resistance of raspberries to fungal pathogens (several of which are collaborative studies described in the report of the Mycology and Bacteriology Department), studies of the inheritance of spinelessness in blackberries and of the tolerance of black currant flowers and fruit to frost and their proneness to premature drop. Studies of the latter have emphasised the complexity of the problem, but the occurrence of a premature drop of 50% in several local plantations of cv. Ben More justified the importance that we attach to it.

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

Very promising results were obtained for the selection 7515C5, both from regional trials in England and Scotland and from commercial appraisal plots in Scotland. This selection ripens in mid season and is notable both for its spine-free canes of moderate vigour, which are easy to manage without chemical vigour control, and for its high fruit quality. It may therefore provide an alternative to cv. Glen Clova, whose vigorous canes present difficulties when the use of dinoseb for vigour control is no longer permitted, and also for cv. Glen Prosen, which is grown for its superior fruit qualities but ripens later than required for major production in Scotland. The Scottish NFT Panel recommended that propagation of 7515C5 should be initiated to hasten its availability to the industry if the promising results are maintained.

Two selections from the current stage 1 trials were recommended for inclusion in regional trials: 7516A10, which is a late mid-season selection notable for its good habit, high yield and processing quality, and 8042E6, which is as early as Glen Clova and superior to it for fruit quality but has very vigorous canes. Experiments to determine an appropriate management system were therefore planned.

Resistance to fungal pathogens

The segregation of resistance to cane botrytis (*Botrytis cinerea*) was studied in 175 plants in five third-backcross families derived from *Rubus pileatus* following the inoculation of up to five canes per plant with a mycelial inoculum. The average size of the resultant lesions was considerably smaller on plants with hairy canes (*H* phenotypes) than on those with non-hairy canes (*h* phenotypes). Gene *H* segregated in four of the families but strong resistance independent of this gene was also identified. This resistance has now been transferred with little or no diminution through four generations of breeding, and so evidence was sought for the segregation of a major gene for resistance which would be indicated by a discontinuity in the resistance levels present within each of the gene *H*/*h* groups of phenotypes. The occurrence of such a discontinuity was established for the first backcross progenies tested previously, but no data are available for second backcross progenies and equivocal results were obtained for the present study of third backcross progenies. Further progenies are now being studied.

Tests of 30 selections in replicated trials confirmed the high resistance found in previous years in certain second backcross derivatives of *R. pileatus* and *R. coreanus* and unexpectedly identified high resistance in one of our advanced selections (7815A12).

In tests of 25 genotypes for resistance to fruit botrytis, the mean percentage of mouldy fruit obtained 3 days after picking ranged from 51 to 99. Resistance in the fruit was not associated with cane resistance or with any identified plant feature but the results showed consistency with those of previous years in respect of the high resistance shown by selections 7936F5 and 7815B8.

Attempts are also being made to transfer resistance to *Leptosphaeria coniothyrium* from *R. pileatus* to raspberries, but there was concern that the level of resistance identified in the second backcross was considerably lower than that of the F_1s. To obtain higher resistance levels, one first backcross and two second backcross selections with intermediate resistance were crossed with an F_1 hybrid and the second backcross selection was also backcrossed to its first backcross parent. The segregation of resistance was then studied in 279 plants in eight families using a similar method to that described above for resistance to *B. cinerea*. The average lesion size of *H* phenotypes was only 77% of that of *h* phenotypes, and the highest frequency of resistant segregants occurred in two of the progenies derived from crossing between first and second backcross hybrids. Forty apparently resistant selections were made: the resistance level shown by many of these was promising, especially among the *H* phenotypes, but further tests are required to evaluate them fully.

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

Resistance to raspberry bushy dwarf virus (RBDV)

The study (*Ann. Rep. 1985*, 78) of the inheritance of the strong resistance or immunity shown by cv. Haida to a resistance-breaking strain (RB) of RBDV was completed. The resistance was found to be heritable and required the presence of gene *Bu*, which confers strong resistance to common RBDV isolates, plus an additional unidentified component whose inheritance was multigenic. The second component is probably a partial resistance to graft inoculation which occurs in varying strength in certain cultivars. Thus only a low proportion of graft-inoculated plants of cv. Heritage become infected, but in Haida and some of its derivatives it appeared that this form of resistance was so strongly expressed that it could not be distinguished from immunity even in a large number of graft tests. It would be difficult to screen for this resistance in a breeding programme. Cv. Preussen was identified as an additional source of resistance to RBDV-RB.

(D. L. Jennings, A. T. Jones[1])

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

The study begun in 1986 (*Ann. Rep. 1986*, 85) to develop a model system for genetically engineering *Rubus* using *Agrobacterium* spp. as vectors of DNA was extended to include strawberry (*Fragaria*) and black currant (*Ribes*).

Bacterial isolates were screened for their ability to infect *Rubus* material by visual assessment of the amount of gall production caused by 'wild-type', non-disarmed isolates. Two *A. rhizogenes* isolates (Ar 2628 and Ar 2629), kindly supplied by IPSR (John Innes Institute), were the most pathogenic.

The duration of incubation with the bacteria affected the size of the galls produced on the plant but not their frequency, which depended on the incidence of wound sites for infection. The duration of incubation was varied from 3 to 7 days and 6 days gave the largest galls.

The previous indications that 50 mg/l of the antibiotic marker kanamycin in the media was effective for identifying kanamycin resistant genotypes were confirmed. However, 11% of the plants remained green when *Agrobacterium* spp. were present, even when they had not been transformed. Higher concentrations of the antibiotic may therefore be necessary.

In vitro micro-plantlets of *Fragaria vesca* L., *F. chiloensis* Duch. and *F. ananassa* Duch. (the cultivated strawberry) formed galls after incubation with *A. tumefaciens* (SCRI isolate 516). Galling occurred to a similar extent on all the cultures tested regardless of the incubation period used (1-14 days), and no galls were observed on non-inoculated controls. This is the first report of galling being induced by infection of strawberries with an

[1]Virology Department

Agrobacterium spp. It indicates that the crop may spread the pathogen during the distribution of planting material but it also offers the possibility of genetic manipulation of strawberry using *A. tumefaciens* as the vector of novel genes.

(R. J. McNicol, J. A. Graham[1])

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

The NFT Black Currant Panel recommended that the late-flowering selection P8/12/7 should be released, though it noted the selection's susceptibility to black currant leaf curling midge (*Dasyneura tetensii*). The selection is to be named cv. Ben Alder.

The Panel also recommended the release of selection F6/3/39, in this instance for PYO and garden use and subject to satisfactory jamming tests. This selection outyielded cv. Ben Sarek in 4 of the 5 years between 1982-1986 and was slightly earlier ripening. It is unsuitable for juice production, but is very frost-tolerant at flowering time and has large fruit which hang well on the bushes when ripe.

A decision on the late-flowering selection P9/8/7 was deferred. This selection is suitable for juice production, is very late ripening and yielded well in 1987 when weather conditions for harvesting were often poor.

Two small bush hybrids from the cross Ben Sarek x cv. Ben Lomond, P10/18/121 and P10/18/116, continued to yield well in regional trials. P10/18/121 was particularly impressive in the ESCA trial at Castle Huntly. Neither of them is suitable for juice processing. At Brogdale, P17/1/23, a hybrid from the cross 243/7 x [(cv. Goliath x cv. Ojebyn) op. x cv. Westra] combined good yield and branch strength with processing quality.

Resistance to reversion virus

Two selections from a cross between cv. Ben Alder and cv. Golubka that did not show symptoms of reversion after two graft inoculations were sent for trialling at Brogdale NFT and by growers. Other symptom-free segregates from this cross and from a cross between P10/18/121 and Golubka were replanted for further assessment after initial selection for agronomic characters.

Frost tolerance at flowering

The performance of the new frost simulation chambers constructed in 1986 (*Ann. Rep. 1986,* 86) exceeded their specifications in respect of temperature uniformity and stability and control of the rate of temperature change. The chambers proved invaluable for screening new SCRI selections and potential parents received from overseas.

[1]IFS Student

Twenty two genotypes were frosted at three stages of flowering — grape, first open flower (FOF) and full flower (FF) in replicated tests. Test plants were cooled to −4°C for 4 h at grape and FOF, and to −2.5°C for 4 h at FF, while control plants of each genotype were kept at 6°C. The percentage survival of the flower buds showed several distinct relationships between frost tolerance and the stage of flowering. As usual, cv. Baldwin was prone to damage at all stages of flowering, as were 243/7 and the Russian cultivars Bieloruskaya and Narjadnaja. Cv. Ben More was tolerant at FOF but was damaged as badly as Baldwin at FF: this sudden decline in hardiness may explain its erratic performance in commerce.

In most cultivars frost tolerance decreased as flowering progressed. These cultivars included Ben Lomond, Ben Sarek, Svyriai and the Swedish hybrid 74020-6, but frost tolerance persisted throughout flowering in F6/3/39, P9/11/14, Ojebyn and the Russian cv. Pilot Mamkin.

In addition to escape from frost by late-flowering, as in cultivars such as Ben Alder, it is increasingly desirable to breed cultivars that maintain tolerance of frost throughout their flowering period.

(M. M. Anderson, R. M. Brennan)

Premature fruit drop

The 1986 field and glasshouse studies of premature fruit drop, or 'run-off' (*Ann. Rep. 1986,* 89), were repeated with minor changes. Most notable of these was the introduction of treatments that subjected glasshouse plants to greater stress by extending the duration of a 2°C cold shock after the flowers had been self- or cross-pollinated from 3 days to 5, 7 and 9 days. Neither the duration of this shock nor the pollination difference had a significant overall effect on the amount of fruit that dropped prematurely, but there were large differences between the cultivars: Ben Lomond was the worst affected with 46% fruit drop, Ben More and Ben Alder had c. 30% and Baldwin was least affected with c. 5%. All the first-order interactions were significant ($P<0.05$) but there was no clear pattern of response to the treatments.

In the field, self-pollinated flowers had significantly less 'run-off' than cross-pollinated flowers of the cultivars Baldwin, Ben More and Ben Alder but not of cv. Ben Sarek or the Scandinavian cultivars Brodtorp and Ojebyn. This result contrasts with that of 1986 when Ojebyn appeared tolerant of inbreeding, Ben Sarek was unaffected and Brodtorp was intolerant. In 1987 Baldwin and Ben Lomond lost over half of their potential crop by premature fruit drop.

This year-to-year variation in results emphasises the difficulty of studying 'run-off' and suggests that an additional factor may be confusing the results. Such a factor could be the incidence of infection of the flowers with *Botrytis cinera* (see page 113).

(R. J. McNicol)

Juice quality

Breeding to combine good agronomic characters with processing quality is the main objective, because the latter is required for commercial acceptance in the UK.

Some 365 fruit samples were analysed using spectrophotometric methods to assess their total pigment concentration (E515 at pH 1.0). The best samples were two selections from the cross P10/9/20 x P9/8/7, P10/9/13 and others derived from P9/11/14. 243/7 is still our best donor of juice quality and several of its derivatives combined the required juice and agronomic qualities.

(R. M. Brennan)

Juice colour stability

Juice samples from 40 black currant genotypes derived mainly from crosses between British and Scandinavian cultivars were analysed using HPLC and spectrophotometric methods. In 20 of the samples the major pigment present was delphinidin-3-rutinoside and in the others it was cyanidin-3-rutinoside. Juices with a high initial total pigment concentration showed a relatively low percentage of pigment loss after 5 months irrespective of the major pigment present. There were no significant differences in the rate of loss of total pigment concentration among the 40 samples, but there was significant variation in the rate of loss of individual pigments.

(J. Taylor,[1] D. L. Jennings)

Essential oils in Ribes

In collaboration with a commercial processor, oils from a range of black currant cultivars were analysed by GLC and also assessed organoleptically. Considerable variation in oil composition was found, and the organoleptic strength and characteristics identified were unrelated to the monoterpene and sesquiterpene components present: they were probably related to unidentified minor compounds.

Several SCRI hybrids had oils with good flavour and aroma. Their parents are being studied to discover the origin of these properties.

(R. M. Brennan)

Resistance of black currant stems to Botrytis

In late July, stems of 22 black currant genotypes were wound-inoculated with mycelia of three isolates of *B. cinerea*, isolate 347 from raspberry canes and two isolates from black currant fruits. The resulting infections were assessed after 3 weeks.

All stems of the Russian cv. Svyriai died above the point of inoculation and severe symptoms were also shown by the Russian cultivars Pilot

[1]Chemistry Department

Mamkin and Bieloruskaya. Cultivars as susceptible as these could suffer considerable yield losses in plantations damaged by machine harvesting. The selections C2/15/40 and C2/1/62 were also badly affected, in spite of the indication of resistance previously shown by the latter (*Ann. Rep. 1986*, 88), but P9/11/14 and the cultivars Ben Sarek, Ben Alder and Narjadnaja were resistant. There was no significant difference in virulence between the three *B. cinerea* isolates.

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

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

The spine-free, semi-erect blackberry 78102E10 maintained its good performance for hardiness, yield potential and fruit quality and was recommended for release as a new cultivar. An application was made for Plant Breeder's Rights and propagation was initiated.

The spine-free purple raspberry 53-14-6 was also recommended for release following its good performance in the NFT. It has potential for types of processing where colour intensity and flavour are of primary importance. Propagation will be started as soon as material is available.

Dominant genes for spinelessness

The previous report (*Ann. Rep. 1986*, 90) mentioned that undesirable effects had been associated with the dominant gene *Sf* for spinelessness in progenies of blackberry-raspberry hybrids. The gene has had similiar effects in hexaploid blackberry progenies, but promising spine-free selections of the latter were made in 1987 from progenies where the gene was present in a different genetic background derived from a second introduction of material from Oregon carrying the gene. Further crosses to incorporate this gene were therefore made.

The most promising dominant gene for spinelessness is the one obtained from the non-chimaeral spineless Loganberry and also described in the previous report. Several large spine-free progenies derived from this parent were planted in 1987. Data on the segregation of spinelessness from this source at SCRI were collated with similar data obtained by our collaborators in Italy and New Zealand: they show that the spinelessness is almost certainly conferred by a single dominant gene, provisionally designated Sf_L, but that segregation frequently deviates from the expected ratios because spine-free segregates tend to be in excess when the spine-free parent is female and deficient when it is male.

The third source of spinelessness being studied is the diploid spine-free mutant of cv. Willamette discovered in Australia. The ratios of spiney to spine-free segregates obtained in material related to this cultivar were again very variable and only a few of them were consistent with the ratio

[1]Mycology and Bacteriology Department

expected for the segregation of a single dominant gene. Work is continuing to discover reasons for the variation. The results from crosses with self-incompatible wild raspberries suggest that linkage with an incompatibility gene postulated to be present in Willamette is not the cause.

Purple raspberries

The fruit-set of early fruit of diploid purple raspberries was again poor, apparently because of low temperatures at flowering time, while that of related tetraploid material was satisfactory. A promising fertile selection was made from a progeny of spine-free segregates obtained by the open-pollination of tetraploids heterozygous for the recessive gene *s* for spinelessness. A larger progeny of this open-pollinated material was planted.

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

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

The selections 78JM10, 79RB28 and 79RN59 continued to perform well in National Trials and were all recommended by the NFT Panel for propagation and inclusion in regional trials. Even in the second year of cropping 79RN59 maintained its large fruit size and 96% of its Class I fruit exceeded 25 mm in diameter.

The selection 69EW30 (cv. Cambridge Favourite x 61G51), to be named cv. Rhapsody, was submitted for Plant Breeders Rights and was given a full recommendation for all parts of the UK by the NFT Strawberry Panel. Healthy stock obtained by micro-propagation was issued to the SNSA and is expected to produce sufficient stock for general release in 1989.

(R. J. McNicol)

Vaccinium *breeding*

In addition to providing support for the assessment of novel bush fruit crops (see p.), the Horticultural Development Council is supporting a small *Vaccinium* breeding programme. Initial crosses were made in 1987 to produce cultivars of highbush blueberry adapted to UK production, with good fruit quality, climatic and edaphic adaptability and disease resistance.

(R. M. Brennan)

NEW BLACKBERRY CULTIVAR

LOCH NESS

The Institute and DAFS have applied for Plant Breeders' Rights for a new blackberry, Loch Ness, bred at SCRI. A stock is being propagated.

Breeder's Number	78102E10
Origin	Complex, from tetraploid North American cultivars and SCRI breeding material.

Canes	Vigorous, sturdy shoots produced in moderate numbers (usually five, ranging from five to nine), spine-free and semi-erect but becoming more erect in older plants. Pentangular, green or pigmented, typically deep purple in autumn but with green areas towards the bases and in unexposed areas. Leaves have five leaflets attached to the petiole by conspicuous stalklets.
Fruiting laterals	Usually about 30 cm long, strong but flexible and with white flowers.
Fruit	Large (typically 4 to 6 g), glossy black and blunt-conical in shape. Firm with a pleasantly sharp flavour. Excellent storage capability but there is a tendency for frozen fruit to turn red when frozen, especially if not fully mature when picked.
Season of ripening	Extends over a long period. Ripens about half its crop in August in England but probably too late for northern parts of the UK.
Hardiness	Very hardy
Yield	High, comparable to those of cv. Bedford Giant except in northern parts of the UK where the season is too short.
Diseases and pests	No exceptional susceptibilities have been identified.
Use	Dessert or freezing.
Mode of propagation	By root cuttings, leaf-bud cuttings, rooted stem tips or tissue culture.

NEW BLACK CURRANT CULTIVAR

BEN ALDER

The Institute and DAFS have applied for Plant Breeders' Rights for a new black currant cultivar, Ben Alder, bred at the Scottish Crop Research Institute.

The National Seed Development Organisation are multiplying stocks and bushes for commercial planting will be available from autumn 1988.

Breeder's Number	P8/12/7
Parentage	cv. Ben More x cv. Ben Lomond
Cropping Season	A late-flowering cultivar which therefore escapes many spring frosts during the flowering period. Its flowering date is generally similar to Ben Lomond, but its harvest date is later, similar to Baldwin.

Productivity	More productive than Baldwin and has outyielded Ben Lomond in many trials.
Growth habit	Growth is fairly vigorous with bushes similar in habit and size to Ben Lomond. Growth in some regions (e.g. W. Midlands) can be dense. Bushes of Ben Alder are easily machine harvested.
Fruit characteristics	Berries are small (c. 140/100 g), and the ripe fruit will only hang on the bush for a limited time similar to Ben Lomond. Fruit quality is excellent with high colour stability and the variety is recommended for juice production and all processing outlets.
Diseases and Pests	Moderately resistant to American gooseberry mildew but susceptible to gall mite, reversion virus and leaf-curling midge.

NEW STRAWBERRY CULTIVAR

RHAPSODY

The Institute and the NSDO have applied for Plant Breeders' Rights for a new strawberry, bred at SCRI.

A stock is being multiplied by the Scottish Nuclear Stock Association Ltd.

Breeder's Number	69EW30
Origin	Raised from a cross between 61G51 and cv. Cambridge Favourite made in 1969. The former was derived from cultivars Talisman and Cambridge Vigour.
Plant	Erect growth with medium to strong vigour. Pale green 'crinkled' foliage with interveinal lighter green areas. Runner production moderate.
Fruit	Large to medium size and conical shape. Attractive, glossy red colour with a tendency for its tip to remain white on the plant but to become coloured after picking. Calyx removal is moderately difficult with a tendency to plug. Flesh is red.
Season	Late mid-season with a 50% pick date 8-10 days later than Cambridge Favourite. Not remontant.
Diseases	Resistant to red core and moderately resistant to *Verticillium*.
Yield	Consistently outyields Cambridge Favourite, often by a substantial margin.
Use	Late season dessert

TISSUE CULTURE

W. POWELL

During the year the Tissue Culture and Cytology Unit transferred from Pentlandfield to Mylnefield and given full departmental status. The formation of a new research group at Mylnefield has involved the recruitment of twelve new members of staff and emphasises the importance of cellular and molecular techniques in future crop improvement programmes. In order to complement the ongoing research, future research activities will focus on:

1. Genome structure and organisation at the molecular level through the development of molecular and biochemical markers. (Restriction fragment length polymorphism).
2. The development of appropriate limited gene transfer systems based on *Agrobacterium* and vectorless strategies.
3. The use of transposon tagging for the identification, isolation and characterisation of appropriate genes for use in transformation systems.

Anther culture of barley [PU 2(d)]

The utilisation of anther culture technology in barley breeding has been limited for three main reasons: low overall yield of green plants, high genotypic dependency and problems associated with an intermediate callus phase. Significant improvements in the method, and hence frequency, of green plantlet regeneration were achieved. Modifications of the culture medium together with orientation of anthers in the up position with one lobe in contact with the medium have been largely responsible for the improvements in anther culture response. In order to evaluate the anther culture protocols further, four F_1 spring barley hybrids were tested. Three hundred and sixty spikes were cultured and 380 green plantlets were regenerated via an embryogenic pathway. The cv. Blenheim was a common parent of these F_1 hybrids and the relatively high response to anther culture may be due in part to this genotype which known to be responsive in culture. A particularly interesting feature of this data was the relative proportion of haploid to diploid regenerants. Approximately two thirds of the regenerated plants were haploid and were colchicine-treated in order to restore fertility. The anther culture-derived plants will undergo preliminary field evaluation during 1988 and will form the basis of further genetical and molecular studies.

In order to complement the anther culture approach experiments were initiated to examine the possibility of regenerating viable plants from isolated barley microspores. Anthers were dissected from the cvs. Tweed and Igri and placed in a petri dish containing 0.3 M manitol. Microspores were released from the anthers by applying gentle pressure and the suspension was filtered through a 100 μm stainless steel sieve. Following centrifugation at 100 g for 3 mins the supernatant was discarded and the microspores were resuspended in 2.5 ml of an anther culture medium. A number of plants were regenerated using this technique. However, the system needs further refinement before a reliable single cell system is available for use in barley genetic transformation.

(W. Powell)

Genetic transformation of potato [PU 1(c)]

Experiments were initiated to effect the genetic transformation of potato cultivars. *Agrobacterium tumefaciens* strains containing the binary plasmid Bin 6 (supplied by M. Bevan[1]) were used in an attempt to transform genetically the tetraploid potato cultivars Pentland Dell and Désirée. Bacteria grown on plates were used to establish overnight *Agrobacterium* cultures and both tuber and leaf discs were submerged in the bacterial suspension for 15 mins. They were then transferred to feeder plates for 48 hrs after which they were transferred to a second medium containing carbenicillin (500 μg/ml), to eliminate the bacteria, and kanamycin (100 μg/ml) to select for plant cells containing the vector marker. Plant regeneration was observed from tuber discs in approximately 6 weeks from the initiation of the experiment. Désirée appeared to be more responsive than Pentland Dell in terms of its regeneration capacity. A number of putative Désirée transformants are being maintained in the presence of kanamycin and will be characterised by means of enzymic assays and Southern blot analysis.

In order to facilitate genetical/molecular studies a number of diploid wild species and dihaploid tuberosum genotypes have been included in the *Solanum* genetic transformation programme.

(W. Powell)

Field performance of tissue culture derived potato material [PU 1(c)]

Twenty three cultivars were propagated *in vitro* and both temperature regime (10 and 20°C) and sucrose concentration (3 and 9%) were manipulated. The *in vitro* derived material was multiplied in a glasshouse in a replicated experiment and the tuber progeny were evaluated in a field experiment at The Murrays Farm. The number of tubers and the total weight of tubers produced were measured. There were significant differences between cultivars and treatments. The mean scores for the

[1]IPSR (Cambridge Laboratory)

tissue culture propagated material was significantly less than the control material. There were significant differences between temperature regimes but not for sucrose concentration. More importantly, significant cultivars by treatment interactions were detected. The implications of these findings for potato breeding are that the ranking of tissue culture derived material may not necessarily reflect its true genetic potential. Caution should therefore be exercised when evaluating the first generation of tissue culture derived material.

(W. Powell, J. Brown[1])

Somatic hybridisation of potato [PU 1(c)]

Protoplast fusion of dihaploid lines offers a precise method for resynthesising a tetraploid with useful characteristics, circumventing the reassortment of the dihaploid genome that might occur with meiotic recombination during sexual hybridisation. Many of the wild diploid relatives of *Solanum tuberosum* possess important disease resistance genes and could also be usefully fused with dihaploid lines to create improved potato genotypes.

To this end, various diphaploid potato lines, tetraploids and wild relatives of potato were established in culture. The initial emphasis has been to establish the optimal conditions of plant growth for the reproducible isolation of good yields of protoplasts for each of the potato lines studied. *In vitro* shoots of all the lines were established and bulked and experiments are in progress to assess the effects of medium modifications. *In vitro* grown shoots and glasshouse grown plants are being examined as a source of mesophyll protoplasts. Various pectinase/cellulase enzyme combinations and purification protocols are being used in an attempt to achieve higher yields of protoplasts. Preliminary studies showed protoplast divisions of one of the wild species following culture of the protoplasts. Individual potato lines are being callused to form a cell suspension from each in order to assess its potential as a source of protoplasts.

The Zimmermann electrofusion machine was used to electrofuse fungal protoplasts of *Phytophthora infestans* (in collaboration with A. M. Campbell[2]) and was also used to fuse non-dividing higher plant protoplasts.

(S. Cooper-Bland, W. Powell)

Biochemical and molecular markers

Traditionally linkage studies have been based on morphological characters but more recently biochemical (isozyme variants) have been utilised. In order to detect useful isozyme variation present in barley, 22 of *Hordeum vulgare* cultivars and nine *H. spontaneum* accessions were screened for a total of 22 different enzyme systems. Of the enzyme systems studied five exhibited variability, esterase, 6-phosphogluconate dehydrogenase, aspartate

[1]Potato Breeding Department
[2]Mycology and Bacteriology Department

aminotransferase, phosphoglucose isomerase and acid phospherase. However, in the germplasm examined the isozyme markers were not sufficiently abundant to provide genetic markers distributed over the barley genome. The availability of restriction endonucleases and cloned nucleotide sequences has made it possible to study plant variation at the molecular level. Cloned DNA sequences can be used to probe specific regions of the genome for the presence of polymorphism at the DNA sequence level: restriction fragment length polymorphism (RFLP). Partial genomic and cDNA libraries have been constructed from barley (Prisma) and potato (Désirée) cultivars. From these libraries, clones capable of detecting RFLPs in cultivated and wild species will be identified and used to initiate the construction of genetic linkage maps.

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

[1]Research Student

MYCOLOGY AND BACTERIOLOGY DEPARTMENT

D. A. PERRY

The work of the Department was extended following the transfer of staff from MLURI (formerly MISR) to work on aspects of the soil biomass and the effects of its components on nitrogen cycling in arable soils. The team consists of a mycologist, a bacteriologist and a zoologist who will examine each of the three main groups of micro-organisms constituting the biomass and determine the effects of a range of environmental conditions and cropping histories on their activities and interactions. One of the first tasks is to improve methods of quantifying the total biomass and progress has been made with direct extraction methods in contrast to indirect incubation techniques. The group will work closely with members of the Physiology and Crop Production Department on the availability of nitrogen to potato roots.

The blackleg disease of potatoes was prevalent in 1986 because the cool wet weather at the beginning of the growing season favoured the development of erwinias and plant infection. However, hot water treatment of seed tubers in a continuous flow machine successfully controlled symptoms in the field and there is now the prospect of a practical method of control being available for this troublesome disease. Progress was made towards understanding the molecular basis of pathogenicity of erwinias by the mutagenesis work carried out in collaboration with the University of Warwick and the results have confirmed the importance of cell replication and extracellular pectolytic enzyme production. Pectolytic enzymes are also implicated in the elicitation of phytoalexin synthesis, although extracts from potato cell walls failed to induce the production of rishitin in tuber slices. However, further work will concentrate on the use of potato cell cultures.

A significant advance towards obtaining genetical transformants of *Phytophthora infestans* was made by the successful production of protoplasts from sporangia and zoospores which were subsequently regenerated. The protoplasts were induced to fuse in an electrical field. Protoplasts were also produced from *Rhynchosporium secalis* and although they were induced to fuse, no genetic recombinants have yet been identified after regeneration. Immunoassays have been developed further to detect *Phytophthora* spp. on raspberry roots and as few as 20 zoospores per ml have been detected in water suspension. ELISA has been used also to quantify the amount of mycelium of *P. infestans* present in potato leaves in studies on the effect of environmental factors on disease development.

The prospect of using biological methods to control several fungal diseases of potato tubers has been revealed by studies of antagonists of pathogens on potato roots and tubers, and a novel method of controlling grey mould on soft fruit with naturally occurring volatile compounds is under investigation. *Botrytis cinerea* has been found in many immature fruits of black currant and may be involved in the cause of 'run off', a condition previously thought to be of physiological origin.

DISEASES OF POTATO

Epidemiology and etiology of blackleg *Erwinia carotovora*[PU 13(a)]

Effect of latent infection by erwinias on yield

Studies on the effect of latent infection by erwinias on yields of potatoes in the field were continued. Seed tubers, cv. Maris Bard were inoculated with three strains of *E. carotovora* ssp. *atroseptica* (Eca) and one of *E. carotovora* ssp. *carotovora* (Ecc). In contrast to the results of the previous season when yields were consistently reduced by up to 25% (*Ann. Rep. 1986*, 103), only two of the Eca strains reduced yields while the third and Ecc increased yields. The different effects were probably due to the wet growing season when plants matured earlier and mother tubers of non-inoculated control plants rotted sooner than in previous years.

The mother tubers of glasshouse-grown plants of cultivars Maris Bard and Pentland Crown (susceptible and resistant to blackleg respectively) were inoculated with strains of Ecc or Eca by taking plants from the pots, applying bacterial suspensions and repotting them. Symptomless plants were sampled 3 weeks later and subsequently at fortnightly intervals and yields of tubers recorded. All strains caused significant reductions in yields in both cultivars. Eca was more damaging than Ecc and more pathogenic strains caused greater losses than less pathogenic forms. Yield reductions were greatest at the second sampling when a maximum of c. 50% was recorded and then became less as the experiment progressed.

(M. C. M. Pérombelon, L. J. Hyman)

Control of potato blackleg by hot water treatment of seed tubers

The continuous hot water treatment equipment developed by Aberdeen Biotechnology Ltd for controlling erwinias on seed tubers was used to treat one stock each of the cultivars Désirée and Morene which were heavily contaminated by Eca. Well sprouted tubers were subjected to temperatures ranging from 50 to 59°C for 5 minutes in late April. Tuber contamination level was reduced progressively from c. 10^6 and 10^4 Eca/tuber on Désirée and Morene respectively in the untreated lot, to <10 at the highest temperature. After planting in the field blackleg incidence in Désirée in September ranged from 29.7 to 2.3% with increasing treatment temperature compared with 64.3% in the plots of untreated seed. Similar results were obtained for Morene except that blackleg incidence was less due to the lower seed contamination level.

Emergence was delayed less at the high temperature in Désirée than in Morene in which severe blanking occurred following the highest temperature treatment. Cultivaral factors combined with desprouting caused by the treatment were probably responsible for delayed or non-emergence. In preliminary tests, Morene tubers treated at high temperatures before sprouting emerged normally. The initial tuber temperature before treatment influenced the effects on emergence and blackleg control.

(M. C. M. Pérombelon, S. Melvin[1])

Interaction between Verticillium dahliae *and* E. carotovora

In continuing studies on the interaction between *V. dahliae* and Eca in Israel, seed of four cultivars were inoculated with Eca and planted in fields infested or free of *V. dahliae*. *Verticillium* wilt symptoms were more severe in plants grown from Eca inoculated seed than from non-inoculated seed. They were most severe in cv. Maris Bard which is susceptible to both pathogens; similar in the cultivars Désirée and Pentland Crown, which are moderately susceptible and resistant to blackleg and tolerant and susceptible to *Verticillium* wilt respectively; and they were least severe in cv. Cara which is resistant to both pathogens. In the *Verticillium* infested field, plant height was related to the incidence of wilt but it was not affected by Eca inoculation in the *Verticillium*-free field. In Maris Bard there was an increase in the number of *Verticillium* colony forming units (cfu) in stems of plants grown from both Eca inoculated and uninoculated seed 70 days after planting. The numbers of *Verticillium* cfu increased later in cv. Désirée and Pentland Crown and they were consistently greater in plants from Eca inoculated seed than in uninoculated controls. There was no increase in *Verticillium* cfu in Cara at any time. Blackleg developed only after inoculation with Eca and its incidence was not affected by the presence or absence of *V. dahliae*.

(L. Tsor[2], A. Nachmias[2], L. J. Hyman, M. C. M. Pérombelon)

Genetics of *Erwinia* spp. [PU 15(c)]

A derivative of Eca strain SCRI 1043 sensitive to bacteriophage lamda was mutagenised with λ ::Tn5 and over 3,200 Tn5 carrying colonies screened for virulence by inoculating stems of micropropagated potato plants. Of nine Tn5 induced mutants isolated that exhibited a reproducible avirulent phenotype, five were auxotrophic and the growth requirements of four of them were identified as uracil, arginine, tryptophan and cysteine. A single mutant exhibited a reduced growth rate and, like the uracil auxotroph, was unable to replicate in potato tissue. Analysis of extracellular enzyme profiles revealed that the remaining three mutants were deficient in the production of both pectate lyase and polygalacturonase. These findings confirmed the important role of cell replication *in planta* and extracellular pectolytic enzyme production in erwinia pathogenesis.

[1]Department of Natural Philosophy, University of Aberdeen
[2]Gilat Experiment Station, Israel

The lamda system for generalised transposon mutagenesis has been extended to a range of other *Erwinia* species, namely *E. cypripedii, E. herbicola, E. rhapontici, E. rubrifaciens* and *E. uredovora*. Three classes of mutants have been identified: auxotrophic: enzyme secretory: and extracellular polysaccharide production.

(J. C. D. Hinton[1], F. Ellard[1], G. P. C. Salmond[1], L. J. Hyman, M. C. M. Pérombelon)

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

The relative importance of erwinias and pectolytic clostridia in initiating and progressing soft rotting of potatoes in store was investigated by inoculating tubers with Eca and clostridia alone and in combination by introducing predetermined cell numbers into wells made in the tuber cortex. Tubers were incubated 1) continuously in air, 2) continuously in anaerobic conditions and 3) anaerobically for 2 d and then in air. Numbers of cells of both bacteria in rotted tissue were determined. Despite washing and surface sterilisation, contamination of tubers by both bacteria prevented an assessment of the ability of either one alone to induce rotting. All inoculated tubers rotted in all the gaseous environments and both erwinias and clostridia were present in all rotted tissue in numbers which were not related to the composition of the inoculum or the gaseous environments.

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

Host pathogen recognition between potato and *Erwinia* spp. [PU 15(b)]

Oligosaccharide elicitors

Work on the detection and purification of potato cell wall components which elicit plant resistance mechanisms has concentrated on developing techniques for growing potato cells in culture and purifying polygalacturonic acid lyase (PL). Differences were noted between potato cultivars in the extent to which rapidly growing callus was formed on agar, and callus obtained from tubers grew more rapidly than that from stem or leaf tissue of micropropagated plants. Large amounts of cell wall material have been obtained from extraction of tubers although it contained small amounts of starch. Carbohydrate absorbing at 235 nm was released from potato tuber cell walls incubated with a culture filtrate of *E. carotovora* concentrated by acetone precipitation indicating the presence of PL. However this wall-released material did not elicit rishitin in a potato tuber slice bioassay suggesting that PL must be free from other wall-degrading enzymes to obtain elicitor-active oligosaccharides. A method of purifying PL by FPLC is being developed using Mono S (cation exchanger), superose 12 (gel permeation), and Mono P (chromatofocussing) columns. Although no phytoalexin elicitor activity was detected in crude enzyme hydrolysed cell

[1]Department of Biological Sciences, University of Warwick

wall material, rapid cell growth occurred on the surface of potato tuber discs after their application implying that other biologically active compounds were present. In addition, bioassays designed to detect phytotoxic activity have demonstrated that hot water extracts of potato cell walls inhibited the formation of lettuce root hairs.

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

The chemistry of resistance of potato to fungal and bacterial plant pathogens [PU 15(b)]

Preformed growth inhibitors

Certain phenolics, selected because they have been reported to be present in potato or may possibly be involved in lignification, were inhibitory to the growth of *Erwinia carotovora* when incorporated in nutrient broth at pH 6. Caffeic acid, cinnamic acid, coniferyl alcohol, ferulic acid, salicylic acid, sinapic acid, scopoletin and vanillic acid inhibited growth to differing extents, for example, scopoletin and salicylic acid reduced growth at 0.1 mg/ml whilst sinapic acid was active only at 1 mg/ml. Chlorogenic acid was not inhibitory at 1 mg/ml. In agar diffusion bioassays, high concentrations of chlorogenic acid (3-10 mg/well) lowered the pH of unbuffered nutrient agar surrounding the wells (demonstrated in Petri dishes containing agar incorporating bromocresol purple) and inhibited growth of the bacteria. The inhibition was considered most likely to be caused by lowering the pH of the agar to below the level at which *E. carotovora* was able to grow. McIlvanes buffer (0.15 M citric acid and 0.3 M disodium hydrogen orthophosphate) pH 3.5 added to wells modified the pH of the agar and also caused zones of inhibition. Increasing the buffering capacity of the agar by the addition of 0.2 M phosphate buffer to pH 6 reduced the radius of the zone of inhibition caused by chlorogenic acid.

Degradation of chlorogenic acid and caffeic acid during the course of aerobic bioassays was apparent in both agar diffusion and liquid bioassays. Chlorogenic acid was associated with the formation of a deep green colour (occasionally brown with some isolates) in agar lacking additional phosphate, and caffeic acid formed a brown colour. With both phenolics the colour intensity was less at low pH (below 6.5), and enhanced in the presence of bacteria. None of the other phenolics tested produced any colour change. The colour formation did not occur when plates were incubated under anaerobic conditions.

(G. D. Lyon)

Preformed enzyme inhibitors

In addition to possibly inhibiting growth of *Erwinia* spp. within the plant, preformed phenolics together with their oxidation products may inhibit extracellular bacterial enzymes. Both chlorogenic acid and its oxidation

[1]Short-term Appointment

products formed by incubating with polyphenol oxidase did not inhibit polygalacturonic acid lyase *in vitro* at concentrations up to 300 μg/ml and only slight enzyme inhibition occurred at concentrations of 300-500 μg/ml. Similarly, there was negligible inhibition of polygalacturonase (PG) by up to 1 mg/ml chlorogenic acid although PG was stimulated by 25 μg/ml chlorogenic acid following oxidation by polyphenoloxidase.

(G. D. Lyon)

Protease inhibitors

A method for assaying protease activity from erwinias has been developed using 1% gelatin as a substrate. Protease from *Erwinia carotovora* ssp. *carotovora* isolate 120 was shown to have an optimum pH of 7.75 and required 1 mM calcium, while none was detected from *E. carotovora* ssp. *atroseptica* isolate V615/1.

(J. Heilbronn, G. D. Lyon)

Survival of *Phytophthora infestans* in soil [PU 14(e)]

Oospores of *P. infestans* were produced on soft V-8 agar (0.5% agar) by crossing A1 and A2 mating types, extracted from the agar and placed in small monofilament nylon cloth packets. The packets were placed on the soil surface or buried 10 cm deep at a site at SCRI. Packets were recovered at intervals and the oospores were counted and their viability assessed by microscopic appearance. Samples of viable oospores were placed on 1% water agar to germinate. During the first few months the viability of oospores fell rapidly in packets on the soil surface but not of those buried in soil. Germination percentages of viable oospores from buried packets remained constant at c. 5% and was similar to those observed in oospore preparations prior to burial.

Seed tubers of cv. King Edward were put in pots of soil infested with 0, 3, 10, 30 and 100 *P. infestans* oospores/g. The pots were put in a controlled environment at 17°C, c. 100% r.h. and half of them were kept wet by watering frequently whilst others were kept dry. None of the plants that grew from the tubers developed blight and no blight was observed on newly formed tubers harvested from the pots.

Attempts to infect freshly harvested tubers of King Edward by spraying mixtures of zoospores from A1 and A2 mating type isolates resulted in low levels of infection. Simultaneous stab inoculation with zoospores of the two mating types using plastic pipette tips were more successful and >90% of inoculated tubers developed blight symptoms. However, no oospores were observed in the tissue of infected tubers.

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

Pathogenicity of *Phytophthora infestans* [PU 14)e)]

Leaves of the R-gene differential series of potato plants grown from micropropagated plants in a controlled environment were inoculated with logarithmic dilution series of zoospores of two different isolates of *P. infestans*. The leaves were inoculated on either side of the midrib of the abaxial surface with 15 μl droplets containing c. 0, 10, 30, 100, 300, 1000 and 3000 zoospores per droplet. With isolate 230 (race 1.3.4.7.8.10.11, A1 mating type) consistent results were obtained only with zoospore concentrations of 1000 and more per droplet, but with isolate 259 (race 1.3.4.5.7.8.10.11, A2 mating type) consistent results were obtained with concentrations as low as 100 zoospores per droplet. At high zoospore concentrations, hypersensitive flecks developed on some incompatible hosts and limited sporulation was observed in a few cases. These results emphasise the need to use a range of inoculum concentrations in tests for virulence.

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

Protoplasts of *Phytophthora infestans* [PU 14(e)]

Viable protoplasts of *P. infestans* were obtained by washing sporangia from agar cultures and incubating overnight in 20 mg/ml NovoZym 234 in hypertonic solutions. Mineral salts were better than organic compounds and the optimal solution was a mixture of KCl and $CaCl_2$ of 1.7 osmolality. Between 50-80% of the sporangia produced protoplasts which burst when put in water and did not fluoresce under u.v. light in calcofluor solutions indicating that cell walls were absent. Protoplasts fused into clumps when polyethylene glycol 4000 was added. They formed new walls, germinated and established colonies when transferred to pea extract broth or agar containing 1 M sorbitol. Protoplasts have also been produced with similar yields and regeneration levels from encysted zoospores.

The sensitivity of protoplasts to oligomycin, phleomycin, genticin and hygromycin has been determined. The minimum inhibitory concentration of hygromycin was 10-20 μg/ml. Attempts to genetically transform protoplasts with a plasmid carrying hygromycin resistance (pANS 7-1) were hindered by the deleterious effect on the protoplasts of the polyethylene glycol used in the procedure. However, some cultures were recovered which were marginally more resistant to hygromycin than the parent culture and further tests will be made to determine if they have been transformed with the plasmid.

(A. M. Campbell, J. M. Duncan, R. Moon[1], S. Gurr[1], J. Kinghorn[1])

Protoplasts of *P. infestans* have been fused using Zimmermann electrofusion equipment. Although regeneration has been observed following treatment it is not yet known if fused protoplasts were among those that regenerated.

(A. M. Campbell, S. C. Bland[2], J. M. Duncan, W. Powell[2])

[1]Plant Molecular Genetics Unit, University of St Andrews
[2]Short-term Appointment

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

Detection of P. infestans *in potato leaves and tubers using ELISA*

Gamma-globulin from antiserum to *P. infestans* produced in a rabbit was tested against leaf and tuber tissue infected with the fungus in plate-trapped antigen ELISA, using alkaline phosphatase conjugated goat anti-rabbit serum to detect antigen-bound antibody. When insoluble polyvinyl-pyrrolidone and sodium metabisulphite were present in the tissue extraction buffer, the method detected the pathogen from 13 μg of plant tissue per ml of buffer, but when either was absent the assay was less sensitive. There was no cross-reaction with erwinias. The technique is being used to quantify growth of *P. infestans* in leaves in different aerial environments.

(J. G. Harrison, R. Lowe, H. Barker[1])

Host range of P. infestans

P. infestans may infect various wild or cultivated solanaceous plant species which could be sources of inoculum initiating epidemics of blight. The abaxial surface of leaves of various species were inoculated with water droplets containing c. 1,800 sporangia of a complex race of *P. infestans* and incubated at high humidity and 20°C. After 10 d the pathogen sporulated profusely on *Solanum tuberosum* L., *S. dulcamara* L., *Lycopersicon esculentum* Mill., *L. pimpinellifolium* Mill. and *Datura stramonium* L. Limited lesions were present on leaves of *Atropa belladonna* L., *Nicotiana tabacum* L., *Solanum nigrum* L. and *Hyoscyamus niger* L. but there was no sporulation. Lesions were not formed on leaves of *Nicotiana sylvestris* Speg. & Com.

(J. G. Harrison)

Effect of soil fertiliser type on susceptibility to late blight

It is sometimes claimed that potato crops grown with organic manure are more disease resistant than those given inorganic fertiliser. To test this hypothesis plants of cv. Bintje were grown in field plots which had received the equivalent of 50 t/ha horse manure or 0.75 t/ha inorganic fertiliser (15:15:21, $N:P_2O_5:K_2O$). No fungicides were applied. Blighted, disease infector plants grown in pots in a glasshouse were placed in the field in mid-July. Foliage blight in the field-grown plants first appeared in plots of each treatment on 7 August and disease severity was assessed visually on 25 August. No differences in the severity of blight were observed between the treatments. The haulm was allowed to die naturally. Tubers from each plot were lifted in mid-September, stored in paper sacks at 4°C and were examined at monthly intervals. There were no significant differences in numbers of rotted tubers at any assessment date.

(J. G. Harrison, R. Lowe)

[1]Virology Department

Contribution of tuber-borne and soil-borne inoculum to the mycoflora on potato roots and tubers

Tubers from a field experiment which was planted with micropropagated (MP) plants, MP plants contaminated with seed tuber peelings, and seed tubers (Ann. Rep. *1986*, 110) were harvested and stored at c. 3°C. The incidence of pathogens and common saprophytes of the tuber surface and on eyes was determined in October 1986 and April 1987 respectively, and results for the latter are shown in Table 1.

Table 1. Effect of mother plant contamination on incidence of fungi on daughter tubers

Fungi	*Mother plant origin*		
	Clean MP plants	Contaminated MP plants	Seed tuber plants
	Incidence (%) in eye plugs of daughter tubers		
Rhizoctonia solani	0.8	8.7	11.2
Polyscytalum pustulans	7.5	33.7	30.0
Helminthosporium solani	4.2	32.5	46.2
Colletotrichum coccodes	1.7	0.0	2.5
Verticillium tricorpus	92.5	100.0	66.2
Cylindrocarpon destructans	2.5	1.2	22.5

The low incidence of the pathogens *Rhizoctonia solani, Polyscytalum pustulans* and *Helminthosporium solani* on tubers from the clean MP plants compared with those from the contaminated MP plants and on the seed tuber plants showed that they were primarily seed tuber transmitted. Similar results were obtained from earlier samples of the tuber surface. The incidence of the pathogens was low on the roots of plants when they were growing in the field.

Colletotrichum coccodes was present on roots and on a high proportion of tubers in October regardless of their origin but, in contrast, the incidence in the eyes in April was very low because the fungus failed to survive the storage period. *Verticillium tricorpus* was primarily soil-borne and present on most of the tubers from both healthy and contaminated MP plants with less on seed tuber plants, while the distribution of *Cylindrocarpon destructans* was reversed suggesting possible antagonism between them.

(E. P. Dashwood)

Effect of continuous cropping on the incidence of fungi on potato roots and tubers

Potatoes cv. Maris Piper were grown for 4 years on the same field plots at SCRI and the incidence of pathogens in the soil and on plants of the same cultivar was compared with that from plots where the same crop had grown

for 1, 2 and 3 years. Soil baiting tests both in the field and in soil samples taken from the plots failed to detect any changes in soil populations related to number of years potatoes had been grown. There were also no significant differences in the yields of tubers from the different cropping histories. Visual assessments of the incidence of diseases on tubers showed that 51% had common scab and 4% black scurf with no differences associated with cropping history. When an eye plug test was applied to detect symptomless infections, 10% of the tubers were infected by *R. solani*, 78% by *P. pustulans*, 26% by *H. solani* and 76% by *C. coccodes* but, again, no significant effects of cropping history were found.

(E. P. Dashwood)

Antagonistic activity of some root and tuber fungi against potato pathogens

Over 80 isolates of fungi and one bacterium were obtained from potato roots or tubers and paired in culture with *R. solani*, *P. pustulans*, *C. coccodes* and *H. solani* on potato dextrose agar and tap water agar using various methods and times of inoculating plates. *Trichoderma viride* and *T. harzianium* were strongly antagonistic to all the pathogens. Several *Penicillium* spp. restricted the growth of *R. solani* but were less inhibitory towards the other pathogens and *Chaetomium* spp. suppressed only *R. solani* and *H. solani*. *Paecilomyces lilacinus* was antagonistic to all the pathogens except *P. pustulans*, but *Gliocladium roseum* showed only moderate inhibition of *R. solani* and *C. coccodes*. One unidentified bacterium was strongly antagonistic to all the pathogens.

(E. P. Dashwood)

DISEASES OF SOFT FRUIT

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

Pathogenicity of Phytophthora *spp.*

Many samples of plants with suspected root rot were received from plantations of raspberry entered for certification in Scotland, England and Wales but only a small proportion were infected by the pathogenic form of *P. megasperma* or the moderately pathogenic *P. cambivora* and *P. citricola*. The remaining samples did not show any aerial symptoms but oospores were present in all the roots. However, the oospores were smaller than those of *P. megasperma* and were distributed throughout the cortex. Papillate sporangia were also observed on the roots and a fungus similar to *P. cactorum* with a slow rate of growth and which was sensitive to hymexazol was isolated on one occasion; it did not infect a range of bait plants previously used to isolate *P. cactorum* and it caused only moderate root rot of red raspberry plants in pot tests. An isolate of the pathogenic *P. megasperma* was obtained from Tayberry plants affected by root rot but it

did not attack this normally resistant host when inoculated in a pot test, even after a period of waterlogging. It did, however, cause severe symptoms on red raspberry. *P. citricola*, *P. cambivora* and *P. drechsleri* caused severe damage to raspberry plants that had been waterlogged for 4 days but 8 days waterlogging were required before any disease symptoms were produced by *P. megasperma* var. *megasperma*.

The effect of temperature on root rotting caused by the pathogenic *P. megasperma* was determined by placing inoculated potted plants in polythene bags in water baths. Symptoms were severe between 10 and 30°C and were less severe at 5 and 35°C. Etradiazole and oxadixyl plus mancozeb gave good control of *P. megasperma* in a pot experiment and they were included, together with metalaxyl plus copper, in a field trial on an infested plantation in collaboration with staff of ESCA. Tests on a sample of roots taken 6 weeks after application of metalaxyl plus copper indicated that the fungus could be isolated from both treated and non treated plants.

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

Detection of Phytophthora *spp. using ELISA*

A comparison was made between different methods of preparation of strawberry and raspberry root samples for testing by ELISA. Freezing samples in liquid nitrogen followed by grinding in a buffer containing Polyclar and sodium metabisulphite gave the most efficient extraction of antigenic components with relatively low background interference. Comparisons were made between plate trapped antigen (PTA) ELISA and a mouse-rabbit antibody sandwich method. The PTA ELISA was more sensitive and faster than the double antibody sandwich technique without increased non-specific reactions. Low numbers of zoospores (c. 20/ml) of a range of isolates pathogenic to raspberry were successfully detected by ELISA.

(E. A. Rees, J. M. Duncan, D. M. Kennedy)

Screening for resistance to Phytophthora *root rot of raspberry*

Plants of four second- or third-backcross hybrids of *Rubus spectabilis* and a red raspberry progeny related to cv. Latham were inoculated with *P. megasperma* but no resistance to root rot was identified. One progeny obtained by crossing a second-backcross hybrid of *R. coreanus* with a similar derivative of *R. piliatus*, both of which had been previously identified as resistant to *Leptosphaeria coniothyrium*, showed some resistance. Clonal material of 15 second- and third-backcross hybrids of *R. spectabilis* were tested by inoculating pot plants with *P. megasperma*. A degree of resistance was detected in only two clones indicating that the resistance of *R. spectabilis* had been reduced to an unacceptable level by backcrossing.

(J. M. Duncan, D. M. Kennedy, D. L. Jennings[2])

[1]Short-term Appointment
[2]Soft Fruit Breeding Department

Raspberry cane spot *(Elsinoe veneta)* [PU 9(a)]

Studies of infection of raspberries by *E. veneta* were facilitated by the development of a new culture system to provide a consistent supply of conidia. Isolates were grown on corn meal agar (CMA) at 20°C to produce microcolonies from which conidia were obtained to 'seed' plates of Czapek-Dox agar supplemented with V8 juice. Discs of agar were taken from 2-3 wk old cultures and floated on sterile distilled water with the mycelium uppermost for 24 h. Conidia were removed from the mycelium and filtered through two layers of tissue to provide suspensions containing 1.0×10^6 conidia/ml.

The growing tips and youngest unfurled leaves of 12 raspberry genotypes were inoculated in a glasshouse in mid-July by brushing on a conidial suspension and covering with polyethylene bags for 48 h. Small red lesions appeared on the canes, petioles and leaf laminae 3-4 wk later. All the genotypes developed lesions; black raspberry selection SCRI 52B6 had the most lesions per cane, and cv. Glen Prosen had the largest individual lesions. Red raspberry selection EMRS 2769/9 had the fewest lesions.

In an inoculated field trial, cultivars Glen Prosen, Glen Moy, Glen Clova and Malling Orion all had a high incidence of cane and leaf infection, but Malling Orion had most lesions and the highest scores for leaf infection. Inoculations done on 18 June produced more lesions than those on the 11 or 25 June when the weather was cooler, indicating that environmental conditions for disease development are important. In Malling Orion results of inoculations made at the shoot tips and on leaves at the third, sixth and tenth nodes below them suggested that only the most juvenile tissues were susceptible.

Histological studies showed that the fungus stimulated extensive enlargement and division of cells, and synthesis of suberin and lignin in the cortex, phelloid cells of the periderm and phloem. Mature suberised phellem cells and phloem fibres that were protected by a lignified middle lamella were not invaded.

(B. Williamson, R. J. Nicol[1])

Scanning electron microscopy (SEM) of raspberry fruits infected by *Botrytis cinerea* [PU 9(a)]

The infection of mesocarp cells of ripe drupelets by *B. cinerea* was studied by SEM. Individual drupelets of ripe fruits of cv. Autumn Bliss were punctured with a fine glass needle coated in dry conidia and incubated in high humidity at 20°C for 24 h. Drupelets were frozen in freon cooled in liquid nitrogen and transferred to a cryostat where they were trimmed on the rotary microtome to expose the wound and surrounding tissues. After freeze drying for 48 h and briefly exposing to air during mounting they were sputter coated with gold. SEM showed intercellular and intracellular

[1]Soft Fruit Breeding Department

hyphae spreading from the inoculated wounds to the large, thin-walled mesocarp cells. The walls of infected cells were swollen and degraded and a zone of damaged cells was present beyond the fastest growing hyphae, indicating an effect of enzymes or toxins of fungal origin. Beyond this damaged zone, apparently healthy cells showed changes in the structure of the middle lamella similar to that observed in healthy, but riper fruits. (see fig. 1)

(B. Williamson, G. H. Duncan[1], A. Dolan)

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

Several volatile compounds from fruits prevent germination of *B. cinerea* conidia and mycelial growth *in vitro*, and the potential of some of them to control grey mould in raspberries and blackberries was tested. Ripe fruits of red raspberry cultivars Autumn Bliss and Heritage and blackberry cv. Ashton Cross were inoculated with conidia of *B. cinerea* and incubated in an atmosphere of high humidity and a range of concentrations of volatiles in sealed plastic boxes. Benzaldehyde at 55 μl/l prevented post-harvest rotting, but methyl salicylate, benzyl alcohol, benzyl acetate and a complex mixture of volatiles from raspberries were ineffective. Benzaldehyde vapour showed fungicidal activity because dead styles from treated fruits were sterile when plated on PDA. However, it has a strong persistent odour at the concentration showing antimicrobial activity. It also gave fruits a dull waxy appearance and induced leakage of juice.

(B. Williamson)

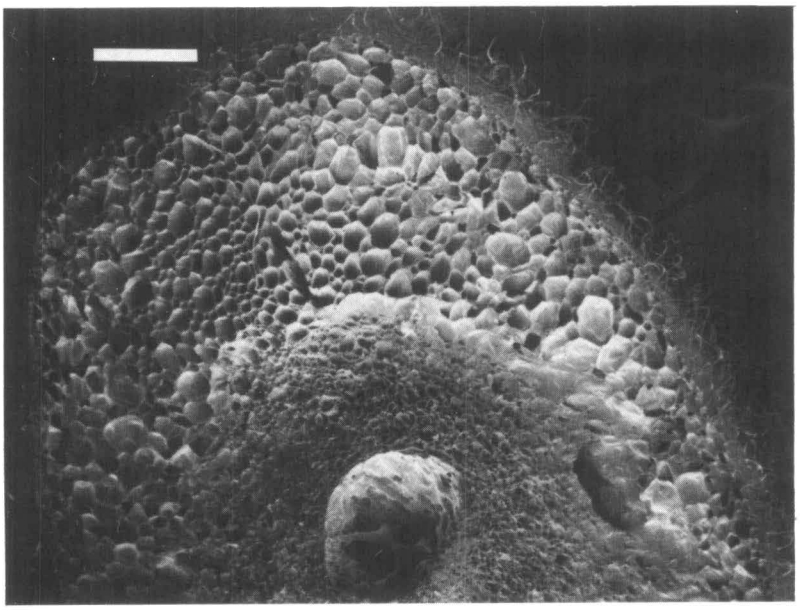
Infection of black currant flowers by *Botrytis cinerea* [PU 9(a)]

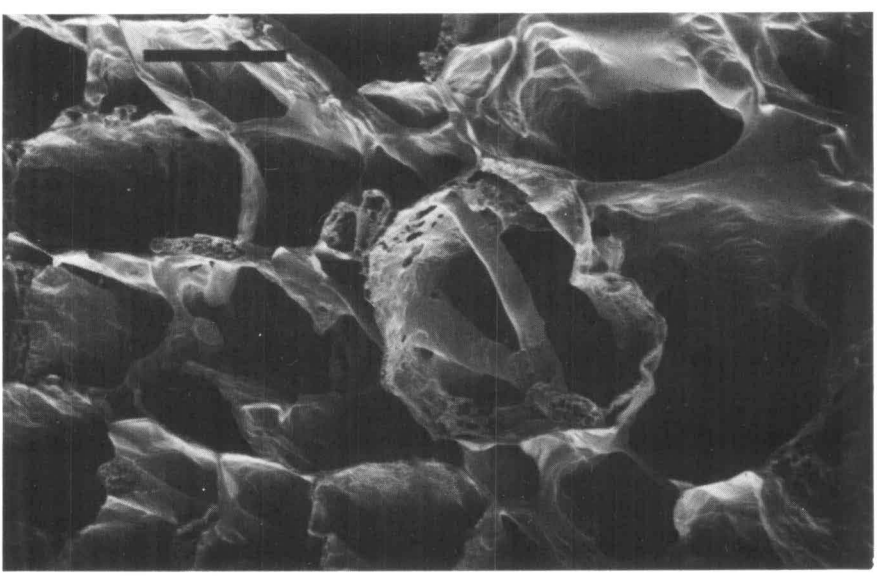
Pre-harvest losses of black currants due to rotting of immature fruits by *B. cinerea* occur in wet seasons despite the use of fungicides. Stigmas of emasculated, pollen-receptive flowers of cultivars Ben More and Ben Alder were inoculated with dry conidia of *B. cinerea* in an unheated glasshouse and pollinated immediately. The flowers were sampled at intervals after inoculation, and examined by u.v. microscopy. The conidia germinated readily in the stigmatic fluid and hyphae grew extensively within all tissues of the style. Only hyphae within the transmitting tissues of the style infected the pericarp and ovules but no visible symptoms were caused. Many apparently healthy green fruits abscissed within 14 days of inoculation and they contained endophytic mycelium.

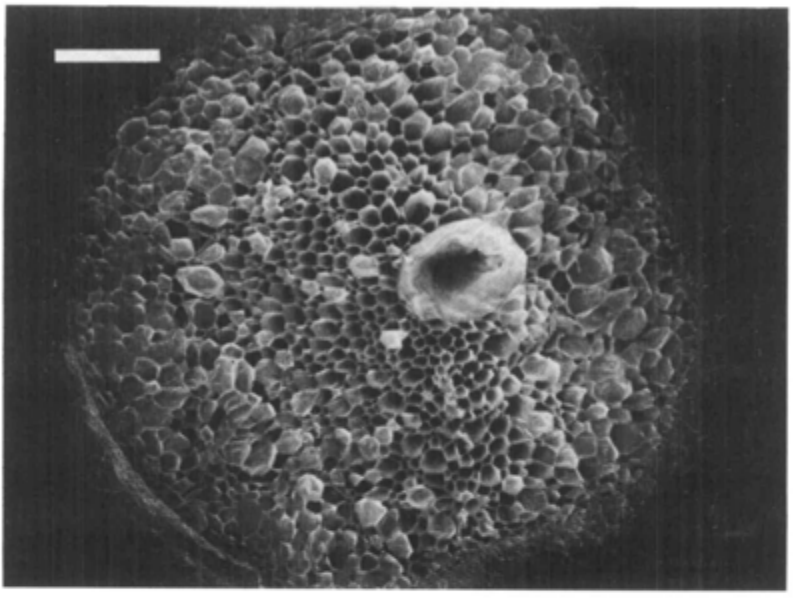
When fully open, intact flowers of cultivars Ben Alder and Ben More were inoculated with conidia of *B. cinerea* in the field none survived to produce mature fruits, whereas c.50% of the uninoculated controls did so; in cultivars Ben Sarek and Ojebyn c. 60% of the inoculated flowers

[1]Virology Department

Figure 1







Infection of a raspberry drupelet by *B. cinerea:* SEM photographs of freeze-dried specimens cryo-trimmed to show a) area around wound (W) destroyed by the pathogen; b) detail of a) showing hyphae inside and between cells; c) an uninfected drupelet with wound. (Bar = 500 μm for a. and c.; 25 μm for b.).

developed fruit and Baldwin and Brödtorp were intermediate. The ovules of prematurely abscissed, apparent healthy green fruits from the inoculated plots were 56-93% infected by *B. cinerea.*

The exceptionally high incidence of endophytic mycelium of *B. cinerea* in abscissed fruits indicates that latent symptomless infection and premature fruit drop ('run-off') may be casually related. Ben More, in particular, is known to be highly prone to run-off and none of its inoculated flowers survived to produce mature fruits.

(R. J. McNicol[1], B. Williamson)

Pathogenicity of *Phytophthora fragariae* [PU 14(e)]

Low and erratic production of oospores *in vitro* necessitated the use of oospores from infected strawberry root systems for genetic studies. A total of 56 single-oospore isolates derived from roots of plants inoculated with parental cultures belonging to five virulence types were examined. All but two of the isolates belonged to the same virulence type as their parent. The two exceptions both originated from parental virulence B66-11A while the progeny belonged to B66-11C. These two virulences are separated primarily by their pathogenicity to cv. Talisman. The results confirmed that new virulence phenotypes are produced relatively infrequently from oospores derived from single oospore cultures in *P. fragariae.*

[1]Soft Fruit Breeding Department

Two single zoospore cultures classified as B66-11B from a line of B66-11B single zoospore cultures which had repeatedly produced single zoospores belonging to B66-3 were inoculated to cv. Cambridge Favourite. Oospores formed in the infected roots were used to inoculate further plants of the same cultivar and of three other cultivars which were not susceptible to the original isolate and which were included to detect new virulence combinations. Only Cambridge Favourite became infected. No new virulence combinations were observed in the recovered isolates but cultures belonging to B66-3 were recovered.

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

Fungicide trials for control of strawberry red core [PU 9(a)]

In the third year of a fungicide field trial on a red core site at SCRI, metalaxyl-based fungicides gave better disease control than several fosetyl-Al treatments on the susceptible cv. Cambridge Favourite. Both fungicides increased fruit yields over those from untreated plots. Similar responses to treatment were obtained from the field resistant cv. Saladin although mean yields over all the plots of this cultivar were low. A rapid method of assessing disease was used in which 10 rooted runners were dug from each plot and scored on a scale of 0-5 for the amount of rotting. The mother plants were also scored for vigour on a 0-5 scale. Both assessments correlated with yield but the former was a more sensitive measure of disease.

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

DISEASES OF CEREAL

Genetical studies on *Rhynchosporium secalis* [PU 8(b)]

In attempts made to demonstrate whether genetic recombination was possible between different isolates of *Rhynchosporium secalis*, several toxin-resistant mutants were isolated. Preliminary experiments produced genotypes of non-parental type but it was found later that similar types could be derived from the parental isolates after storage and single spore selection. Thus the new genotypes were likely to have a cytoplasmic component and the putative recombinants were probably due to cytoplasmic fusion between isolates. Three unambiguous mutant phenotypes were identified which were stable and presumably nuclear mutations. Protoplasts were obtained from them and attempts made to fuse the protoplasts but no recombinant genotypes were detected. Isozyme analysis of mutants, putative recombinants and their parental isolates showed variation for two enzymes between parental isolates and their mutant derivatives.

(A. C. Newton)

Computer and biochemical methods for quantifying partial resistance to mildew [PU 2(e)]

A method for extracting sterols from infected leaf segments was devised using capillary gas chromatography and a single peak which was assumed to be derived from fungal cell walls was correlated with the quantity of mildew present. Preliminary results indicated that some partially resistant barley genotypes limited the amount of fungal biomass in the leaf more than expected from visual assessments. The Quantimet image analyser was used to assess the area of mildew lesions on leaves but it was difficult to accurately discriminate between varying leaf background colour, particularly chlorosis, and mildew colonies. Cross polarised light and a polariser on the camera overcame the difficulty to some extent, but the threshold had to be set manually for each leaf introducing a subjective element. Results correlated well with colony number counts but less well with sterol measurements suggesting that the Quantimet was measuring only the denser colony centres rather than the total area.

(A. C. Newton)

Genetic adaptation of mildew to partial resistance in barley [PU 14(e)]

Measurements of infection frequency and colony length demonstrated that one out of 10 isolates of mildew tested showed adaptation to a partially resistant cultivar Cornutum. Partial resistance in Cornutum was expressed as restricted colony length and infection frequency while in other partially resistant cultivars only infection frequency was reduced under the experimental conditions used. Recombination data analysis indicated that there may be a major gene component of resistance in Cornutum which was not present in the other cultivars. Extracts were made from leaf surfaces of a selection of cultivars including Cornutum, developed on thin layer chromatographs and assayed for biological activity with *Cladosporium* sp. to determine whether the restriction in colony growth was associated with any biochemical component. Several inhibition zones were detected, but with one exception they showed variation in neither quantity nor quality between the cultivars. One of the extracts from Cornutum produced a strong inhibition zone on one occasion, possibly associated with the growth conditions at that time.

(A. C. Newton)

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

Six cultivars of winter barley growing in pots in a low temperature controlled environment differed in their susceptibility to snow rot when inoculated with sclerotia of *Typhula incarnata* and treating seed with triadimenol plus fuberidazole before sowing controlled snow rot except in the most susceptible cultivar, Sonja. The fungicides triadimenol, propiconazole and benodanil were each applied to cv. Igri growing in pots at low

temperature 1) concurrently with inoculation with *T. incarnata*, 2) 4 wk later, and 3) 6 wk later when they were removed from the low temperature environment. Snow rot was controlled more effectively by the first than by the second application and triadimenol gave better control than benodanil with propiconazole intermediate. The late application of the three fungicides after disease symptoms were well advanced did not enhance plant recovery after transfer to a glasshouse.

Isolates of *Fusarium nivale* resistant to benzimidazole fungicides and tolerant of triadimenol (*Ann. Rep. 1986*, 100) were inoculated to plants in a low temperature environment. Carbendazim controlled symptoms caused by the sensitive isolate but not those induced by the resistant form. Similarly, the triadimenol tolerant isolate caused more leaf rotting compared with the sensitive isolate after application of triadimenol.

(D. A. Perry)

DISEASES OF BRASSICA

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

Previous work with forage and oilseed rape grown in controlled environments indicated that the rate of clubroot development rapidly declined at temperatures below 15°C (*Ann. Rep. 1986*, 101). The effects of autumn sowing dates was investigated using three oilseed rape cultivars grown in a polythene tunnel. Plants were inoculated 7 days after germination and planted at 2-weekly intervals commencing on 4 August. Some plants from each sowing date were scored for clubroot symptoms 7 to 9 weeks after inoculation while others were kept to determine mature plant disease symptoms. Plants sown early in August were all infected and rapidly developed severe clubroot symptoms and the plants which were grown on died during the autumn. Plants sown between 17 August and 14 September were all infected but clubs were smaller than those on plants sown earlier and the retained plants were mostly healthy in December. Plants sown after 14 September were uninfected and retained plants were healthy in December. The results confirmed that infection and pathogen development were inhibited in daylengths less than 12 h and a mean daily temperature less than 12°C.

(C. J. Williamson)

Genetic control of resistance to *Plasmodiophora brassicae* [PU 15(c)]

The *Brassica rapa* European Clubroot Differential (ECD) host 04 has been reported to have three dominant genes for resistance to clubroot, and the ECD hosts 01, 02 and 03 each to have two of them. A crossing programme based on four plants from each of the ECD hosts 01, 02 and 03 was

designed to separate and identify each of the resistance genes. A population of *P. brassicae* pathogenic on ECD 04 was used to test some of the progenies from the crossing programme and resistance to this population, not previously reported, was identified in ECD 03. The results suggested that there was some heterogeneity for this new resistance in the parental ECD 03 and ECD 02 populations.

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

DISEASES OF BEAN

Phytoalexin production in relation to bean leaf age [PU 15(c)]

More lesions developed and they expanded faster on old than on young bean leaflets after inoculation with similar numbers of conidia of *Botrytis fabae*. HPLC analysis of tissue extracts showed that higher concentrations of the phytoalexins wyerone and wyerone acid accumulated in young than in old leaves after being challenged with *B. cinerea*. Differences in susceptibility to chocolate spot disease between young and old leaves may be related to their ability to synthesise phytoalexins.

(J. Heilbronn, J. G. Harrison)

SOIL MICROBIOLOGY

Measurement of soil microbiological parameters [PU 17(f)]

A suite of methods for estimating a wide range of soil microbiological parameters has been developed. Collectively, the procedures provide a comprehensive overview of the microbiological status of the soil in relation to the N-cycle. Emphasis has been placed on rapid methods which permit widespread screening of many soil samples. The methods provide information about the size of inorganic N-pools, the size, composition, activity and N-status of the microbial biomass, and potential mineralisation, denitrification and volatilisation of nitrogen compounds.

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

Effects of N fertilisation upon soil microbial biomass

In a field study on the effects of N fertilisation of potatoes upon some soil microbiological parameters, potato cultivars Cara and Pentland Dell were fertilised at rates of 0 or 125 kg N/ha. There was no significant difference between the performance of either cultivar within each fertiliser regime, and N fertiliser significantly increased both crop mass and tuber yield. The size of the soil microbial biomass, estimated by the chloroform fumigation-incubation technique, tended to be reduced by N fertilisation. Soil microbial

[1]Brassica Breeding Department

activity, measured as the ability of the biomass to produce formazan from a tetrazolium salt, was significantly reduced by N fertilisation and was consistently lower in the top 15 cm of the planting ridge than below this depth. There was no significant effect of cultivar upon either size or activity of the microbial biomass.

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

Incubation temperatures for soil gas studies

Incubations for soil gas analyses are conventionally done over a short time period at room temperature to ensure a rapid and easily-measured appearance of the product gases and rely on passive diffusion of the gas from the soil to the headspace in the apparatus. When the soil is very wet a low rate of accumulation of gas, e.g. carbon dioxide, in the headspace may be due either to a low catabolic rate in the soil, or a slow rate of diffusion of the gas through the soil water. Acidification of the soil sample after incubation will cause a rapid release of carbon dioxide from the soil solution since the gas is relatively insoluble under acid conditions. Comparisons of samples with and without added acid showed a marginal increase in the concentration of carbon dioxide in the headspace but no increase in the rate of carbon dioxide evolution. It therefore appears that the rate of carbon dioxide evolution was accurately measured, even when very wet soils were incubated for short periods. This was not the case when nitrous oxide production was measured to determine denitrification. When very wet soils were given short-term incubations, e.g. 4 h at 20°C, little or no nitrous oxide appeared in the headspace, indicating a very low rate of denitrification. However when the samples were incubated at a lower temperature, e.g. 10°C for several days, a rate of nitrous oxide accumulation equivalent to a high rate of denitrification occurred. The rate remained linear throughout the incubation and the longer term of the incubation appeared to have no effect on the microbial population. Samples for gas studies are now incubated routinely at the lower temperatures of 10-15°C, which also relates more realistically to soil temperatures.

(R. E. Wheatley, K. Ritz)

Effects of protozoan grazing on nitrification

The relationship between protozoan numbers and nitrification was investigated in a series of soil incubations. It was not appropriate to sterilise soil to rid it of protozoa because ammonium-oxidising bacteria required for nitrification failed to grow when inoculated into sterilised soil. The addition of thiram, cycloheximide and Triton X-100 to soil to reduce protozoan numbers reduced the accumulation of nitrate, the rate of ammonium oxidation and numbers of ammonium oxidisers. Adding glucose or mannitol to soil to stimulate protozoan activity reduced nitrification. This was attributed to the action of heterotrophic micro-organisms inhibiting the autotrophic ammonium oxidisers. Experiments in liquid culture also demonstrated that nitrification was enhanced by the presence of protozoa and reduced by heterotrophic activity.

(B. S. Griffiths)

ZOOLOGY

D. L. TRUDGILL

The Zoology Department is continuing to research alternatives to synthetic chemicals for controlling pests. The value of plant resistance and biological/cultural methods of pest control has long been recognised and work in these areas is continuing, but the importance of plant tolerance of pest damage is now being more widely appreciated. In potato we have demonstrated large differences in tolerance between cultivars and identified some of the mechanisms involved; with swede, growing tolerant cultivars has been identified as the most economic means of minimising losses due to nematodes; and in fodder and oilseed rapes large differences have been demonstrated in cultivar tolerance of root fly damage. However, in raspberry, the promise based on pot-test results of cv. Glen Moy being relatively tolerant of re-plant disorders in the field was not fulfilled.

Resistance to potato cyst nematodes is a major area of study and results are reported demonstrating the value of using partially resistant cultivars in integrated control programmes. A method for making comparative assessments of plant resistance and nematode virulence, which has been presented for adoption by the European Plant Protection Organisation, is described. A new rapid method of screening for resistance to raspberry aphids has been proven and progress made in understanding the mechanisms of swede resistance to root fly attack.

Fungi which kill cyst nematode eggs, are known to be important biocontrol agents. It has now been shown that they have a second mechanism of action, stimulating hatch of uninfected juveniles which would otherwise remain dormant to await the planting of a host crop. Studies on the occurrence of carbohydrates/glycoproteins on nematode cuticles have continued, confirming their widespread occurrence. These carbohydrates appear to be involved in a number of processes, including the functioning of sense organs, the establishment of cyst nematode juveniles, and possibly the recognition of nematodes by parasitic fungi.

Pest development can often be measured on the basis of thermal time and this has been applied to model the timing of emergence of raspberry cane midge. It has also been used to predict the likelihood of the northern root-knot nematode becoming a pest in Finland and Scotland. Laboratory studies have demonstrated that adult clay-coloured weevils attacking raspberry are long-lived, adults continuing to lay eggs over at least two summers.

Work on virus transmission by nematodes is concentrating on the associations between Trichodorid nematodes and tobacco rattle virus (TRV) — the main cause of spraing in potatoes. Using very precise techniques and through collaboration with the Virology Department we have shown that different species of Trichodorid transmit different serotypes of TRV, with some species transmitting more than one serotype. Further evidence has also been obtained for a very high degree of specificity between nepoviruses and their longidorid vectors, with populations of a vector species differing in their ability to transmit isolates of virus within the same serotype.

Other work includes studies on the nematicidal properties of a natural plant product, the isolation of stress compounds from potato exposed to potato cyst nematodes, evidence that in the summer of infection potato plants do not act as a significant source of potato leaf roll virus (PLRV), and that insecticides still provide some control of PLRV spread by insecticide resistant strains of *Myzus persicae*.

Assessment of partial resistance in potato to different potato cyst nematode populations [PU 1(e)]

In 1984, a meeting held under the auspices of the European Plant Protection Organisation recommended that a study should be made of the methods of assessing partial resistance in potatoes and differences in virulences between nematode populations with a view to making recommendations for an international scheme.

To this end, three experiments, co-ordinated from SCRI, were made in collaboration with centres throughout the UK, the Netherlands, France and Germany. The first assessed potato clones which encompassed a range of partial resistance at several centres using one population of *Globodera pallida*. The second experiment, repeated at only two centres, tested the same clones but with six populations of *G. pallida* thus eliminating differences in environment and examining differences between and interactions with these populations. The third experiment was conducted at all centres, again with the same clones, but with each centre using its own population of nematodes to study the confounding effects on the assessment of resistance of having different populations and different environments.

The results showed that the largest differences were between clones and between the sites. There were also differences in the overall virulences of the populations but these were small in comparison to the differences in resistance between the clones. In the first two experiments the interaction between clone and environment and clone and population were very small, accounted for only between 4 and 6% of the total variation. In the third experiment, where the effects of centre and population were confounded, the interaction was slightly larger, accounted for 9% of the total variation.

There were large differences in the mean multiplication rates of nematodes between centres and these demonstrated the inappropriateness of the present system of using absolute rates of multiplication as a measure of partial resistance, or as a means of delineating pathotypes. The experiments showed, however, that despite the small interactions between clones and populations or environments the resistances of the clones were ranked in a similar order, confirming our proposal (*Ann. Rep. 1985*, 106) that clones with well established levels of resistance could be used as standard or reference clones against which unknown test clones can be evaluated. The results also showed that when the mean virulence of the populations was expressed as a percentage of the non-resistant controls, the populations were also ranked in the same order of virulence at the different centres. These studies have therefore shown that just as resistance should be described in relation to certain reference clones so too the virulence of populations could be described relative to reference populations.

(M. S. Phillips, D. L. Trudgill)

Population dynamics of potato cyst nematode (PCN) *Globodera pallida* on partial resistant potato cultivars [PU 13(h)]

A series of nine trials in collaboration with the Potato Breeding Department and ADAS compared the resistance of a range of potato genotypes at sites heavily infested with PCN, *G. pallida*.

The overall PCN multiplication rate varied between sites but the relative resistance of the clones was consistent. With the non-resistant control clones the PCN population density increased even in plots treated with the nematicide aldicarb (Temik 10G, 3.3 kg a.i./ha). The partially resistant clones reduced the rate of multiplication, especially at the most heavily infested sites, and generally reduced populations when combined with aldicarb. The results showed, however, that PCN multiplication rates are strongly affected by the total fresh weight of host growth (Table 1). Two very vigorous clones (susceptible cv. Cara and partially resistant clone 12243), both of which are tolerant of PCN damage, caused the PCN population density to increase more than equivalent non-tolerant clones

Table 1. Mean multiplication rates of *G. pallida* on four potato genotypes.

	Site I		*Site II*	
Eggs/gm soil	100.9		25.7	
Genotype	*Untreated*	*Treated*	*Untreated*	*Treated*
Cara	11.6	7.7	13.5	2.3
Pentland Dell	3.0	3.4	8.1	2.9
12243	4.1	2.6	8.2	1.0
ZB35-29	0.5	0.3	0.3	0.2
Mean of all partial resistors	0.8	0.3	1.6	0.4

(cv. Pentland Dell and ZB35-29). These results demonstrate that at heavily infested sites some partially resistant clones, especially if vigorous and tolerant, can cause populations of PCN to increase to a greater extent than non-tolerant, susceptible clones.

(M. S. Phillips, M. F. B. Dale[1])

An agronomic study of the effect of potato cyst nematodes (PCN) on tuber yields [PU 13(h)]

A field site was produced with a range of population densities of *Globodera pallida* by differential cropping between 1981 and 1983. Two cultivars, one tolerant of PCN damage (cv. Cara) and one intolerant (cv. Pentland Dell) were grown as split plots in 1987. The ground cover and the haulm weights were measured at frequent intervals to predict total dry matter productivity and final tuber yields.

A preliminary examination of the results confirmed the much greater tolerance to damage of Cara compared with Pentland Dell. In the most heavily infested plots maximum haulm weight was decreased by 46% for Cara compared with 75% for Pentland Dell. However, fresh tuber yield and maximum dry matter productivity were decreased proportionally less for Cara (24 and 18% respectively) than for Pentland Dell (66 and 44%). This was because Cara produces larger tops than Pentland Dell and the reduction in mean percentage ground cover, and hence light interception was consequentially less for Cara (18%) than for Pentland Dell (56%). These field results support an earlier suggestion (*Ann. Rep.1985*, 106) that the large top of Cara reduces the impact of nematode damage on light interception and makes a major contribution to its tolerance.

(D. L. Trudgill)

Pathotypes of potato cyst nematode (PCN) [PU 15(d)]

The PCN introduced into the British Isles probably comprised only a part of the original South American nematode gene pool. From electrophoretic and morphological studies it is clear that a number of distinct introductions occurred, the most distinct being pathotype Pa1 of *Globodera pallida* introduced into Northern Ireland. It has been proposed that on mainland Britain there are three pathotypes of *G. pallida* (Pa2, Pa3 and New Leake) the most obvious basis for which would be that they derive from three separate and distinct introductions. However, electrophoretic studies have, as yet, indicated no consistent differences between British populations which correlate with these pathotypes, supporting earlier suggestions that they are artifacts of the testing procedure. However, variations have been detected in the occurrence of certain isozymes which are probably a consequence of alleles being lost as PCN was spread from field to field within Britain.

(M. S. Phillips)

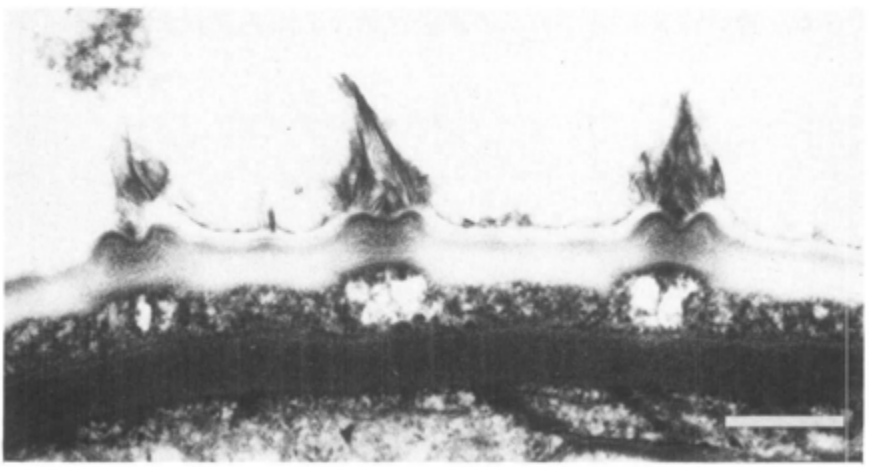
[1]Potato Breeding Department

Changes in potato roots induced by potato cyst nematode (PCN) [PU 15(a)]

Juveniles of PCN invade the roots of resistant potatoes in large numbers (*Ann. Rep. 1983*, 77) but the plant reaction is unfavourable for their development into adult females. The resistant reaction may be elicited by the act of invasion or later when the nematode injects saliva to start induction of feeding syncytia. Roots of potato clone 8917b(3) (90% resistant, ex-*vernei* derived) and cv. Home Guard (susceptible) growing on a sterile nutrient agar medium were inoculated with juveniles of *Globodera rostochiensis* and harvested after various intervals for processing into Spurr's resin and examination with a transmission electron microscope.

In roots taken 5 days after infection serial sections through the head region of the juvenile nematode revealed a matrix containing numerous fibrils which appeared to have been exuded from the amphids and body annules (Fig. 1). This matrix, which is thought to cement the nematode in position, was present around nematodes in both resistant and susceptible roots. However differences were observed in the syncytia. In resistant 8917b(3) the syncytial cell wall was thicker than in susceptible Home Guard whereas the feeding plug (through which the stylet is inserted) was less substantial in 8917b(3) and the plasma membrane could only be seen around feeding plugs produced in Home Guard. In Home Guard the cytoplasm was rich with organelles and nematode feeding tubes whereas in 8917b(3) the cytoplasm lacked organelles and feeding tubes and had a distinct granular appearance. After 9 days a well developed syncytium had been formed in Home Guard but in 8917b(3) the syncytial wall around the feeding plug had disintegrated and there was little evidence of syncytial development.

Figure 1 (J. M. S. Forrest)



Fibrillar material extruded onto the cuticle surface of second-stage juvenile of *G. rostochiensis* sedentary in potato root. Scale bar ≡ 500nm.

Intervention in the host finding responses of potato cyst nematode (PCN), *Globodera rostochiensis* [PU 15(a)]

After hatching, juveniles of PCN find potato roots by following gradients of root exudates. Large sense organs called amphids are thought to be the receptors of these chemical stimuli. Blocking the reception of the root exudates would reduce invasion, damage and nematode multiplication.

An *in vitro* test was devised to study attraction of PCN to agar disks containing potato root exudates (*Ann. Rep. 1986*, 121). Treatment of juvenile PCN with the oxidant chemical sodium hypochlorite removes the glycoprotein exudate which fills the amphidial canal. The test demonstrated juveniles so treated were unable to detect sources of potato root exudate.

The same test was subsequently used to study substances with other modes of action. A pretreatment with the cationic detergent cetyl trimethylammonium bromide (CTAB) markedly reduced migration by juveniles to the root-exudate whereas Triton X100, which is non-ionic, had no effect. Electron microscopical studies revealed that CTAB had caused structural changes in the amphidial exudate and it seems probable that the positive charge on CTAB enhanced its binding effect on the negative charged surface of the nematode.

The lectin concanavalin A specifically binds to mannose/glucose residues and was shown to bind to the amphidial exudate and head of PCN juveniles (*Ann. Rep 1985*, 109). Control of root knot nematode by low concentrations of concanavalin A applied in microplots has been reported by others. However, we found no effect of concanavalin A on the attraction of PCN juveniles to potato root diffusate. This suggests that in PCN mannose/glucose residues are not responsible for capturing rapidly diffusing stimuli from potato roots. Similarly, cationized ferritin, a large, postively charged protein, also bound to the surface of the amphidial exudate in PCN juveniles but again treatment did not reduce host-finding. In contrast, spermidine, a small cation found *in vivo* associated with polyanions, did reduce host finding by PCN juveniles possibly because it was transported through the amphidial exudate to directly affect the sensory receptors.

(J. M. S. Forrest, Y. Spiegel[1], W. M. Robertson)

Role of surface carbohydrates in host/pathogen recognition [PU 15(a)]

Carbohydrates located on the outer cuticle of plant parasitic nematodes are being examined since it is possible that these molecules play an important role in interactions involving nematodes and plant roots or nematode pathogens. *Anguina tritici, Aphelenchus avenae, Bursaphelenchus lignicolus, Longidorus elongatus, L. macrosoma, Meloidogyne incognita, Pratylenchus penetrans, Tylenchorhynchus claytoni* and *Radopholus similis* were screened with rhodamine conjugated lectins from *Arachis hypogaea* (PNA), *Canavalia*

[1]Volcani Centre, Bet Dagan, Israel

ensiformis (Con A), *Limax flavus* (LFA), *Triticum vulgaris* (WGA) and *Ulex europaeus* (UEA). Following blocking experiments with appropriate complementary sugars, N-acetylglucosamine residues were identified on the head, amphids or amphidial exudates of *A. tritici, R. similis* and *T. claytoni*. D-glucose and/or D-mannose residues were found in the same regions on *B. lignicolus, M. incognita* and *P. penetrans* as well as galactose residues on *M. incognita*. N-acetylglucosamine was localised at pore openings of *L. elongatus, L. macrosoma* and *R. similis* and was found distributed over the entire body of *A. tritici*. Both *Longidorus* species also labelled for galactose residues at the sides of the anterior end. All lectins were rapidly taken into the body of *A. avenae* and appeared as non-specific labelling in lipid droplets.

(W. M. Robertson, Y. Spiegel[1], H-B. Jansson[2], N. Marban-Mendoza[3], B. M. Zuckerman[4])

Saccharide moieties on *Pratylenchus penetrans* [PU 15(a)]

A more detailed lectin binding study was made of the surface sugars on adults and juveniles of *P. penetrans* extracted from roots of raspberry. Tetramethylrhodamine (TRITC) conjugates of concanavalin A (Con A) and agglutinins from *Dolichos biflorus* (DBA), *Glycine max* (SBA), *Ulex europeaeus* (UEA) and *Triticum vulgaris* (WGA) were applied alone or with their respective sugar haptens (∝-methyl mannoside, N-acetyl galactosamine, fucose and N-acetyl glucosamine).

Con A, SBA and WGA bound specifically to a small area at the tip of the head of some adults and juveniles. UEA also bound to some individuals of all stages, but part of the binding could not be blocked completely by fucose and therefore probably was non-specific. Although DBA has a similar sugar specificity to SBA, it did not bind to any of the nematodes, perhaps indicating that conformational differences in the nematode glyco-conjugates can influence lectin specificity.

(J. M. S. Forrest, A. L. Zepp[5])

Host recognition: chemotactic and electrotactic localisation of plant roots by parasitic nematodes [PU 15(d)]

Nematodes tend to be attracted to only one or more of the following root zones: root elongation; sites of lateral root primordia; root galls; and wound sites, especially those caused by nematodes. Not only are a range of chemical diffusates emitted from these zones but also they are the sources of relatively large electrical fields. Preliminary studies using an artificial matrix have established that *Xiphinema index, Longidorus elongatus* and

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[4]Department of Plant Pathology, University of Massachusetts, USA
[5]Research Institute of Pomology, Brzezna, Poland

Anguina tritici are attracted to the cathode at field strengths up to 6 V/cm, voltages equivalent to those generated by roots. *G. rostochiensis* appears to be unaffected by these electrical fields but is strongly attracted by root diffusates.

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

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

The summer of 1984 was unusually warm and some potato plants showed symptoms in early July of current season infections with PLRV. This and the spatial distribution of plants subsequently shown to be infected, suggested that some PLRV might have originated from these plants showing primary infections. This possibility was tested in experiments in 1986.

In the glasshouse, aphids (*Myzus persicae*) were allowed to feed for 4 or 5 days on potato plants grown from PLRV-infected tubers (secondary infectors) and then for 4 days on 2-3 week old, virus-free plants of cv. Maris Piper; plants infected with PLRV were subsequently identified by ELISA and used as 'primary' sources of PLRV.

The age of the virus source plant was shown to have a major effect on subsequent transmission rates. The secondary source plants were best as virus sources when 2-4 weeks old and no infections were obtained from 8 week old plants. In tests using 6 week old secondary sources plants aphids subsequently transmitted PLRV to 11 out of 24 *Physalis floridana* test plants. In contrast, with tests using the primary source plants no transmissions occurred in 106 tests with aphids exposed to 6-8 week old plants but with 10 week old plants eight out of 24 virus test plants were subsequently infected with PLRV.

In the field, single stemmed plants of cv. Maris Piper (Super Elite (SE) Grade) were infected in mid June (Test 1) or early July (Test 2) by grafting scions from 5 week old plants secondarily infected with PLRV. Three to 5 weeks later groups of *M. persicae* were caged for 5 days on young expanded leaves of the grafted plants which served as primary infectors. They were then caged for 5 days on uninfected plants of the same age in neighbouring drills. Infection of these plants with PLRV was assessed first by ELISA in September and then visually the following summer (1987) by growing 12 tubers harvested from each plant. In addition, tubers from each of the primary source plants were also grown in 1987.

The results (Table 2) show that ELISA did not always detect primary infections in the grafted plants, probably because the titres of PLRV antigen were low when aphids were caged on them. In the transmission tests one of 59 plants was infected with PLRV (Table 2). It is concluded that primary infections are unlikely to provide additional sources of PLRV for spread by aphids in Scotland.

(J. A. T. Woodford)

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Table 2. Number of plants (cv. Maris Piper) infected by PLRV (numerators) out of total numbers assessed (denominators).

Sampled plants	Date of infection (plants & aphids)	*Assessment method* ELISA (1986)	Visual (1987)
Test 1			
Grafted plants	18.6	6/14	10/18
3 week aphid-transmissions	14-19.7	0/29	0/27
5 week aphid-transmissions	28.7-2.8	0/17	1/17
Test 2			
Grafted plants	11.7	5/15	7/14
5 week aphid-transmissions	18-23.8	0/15	0/15
Uninoculated plants	—	0/14	0/60

Control of aphid vectors of potato leafroll virus (PLRV) [PU 13(g)]

Populations of *Myzus persicae* resistant to organophosphorus and carbamate insecticides are widespread in potato crops in Great Britain but little is known of their ability to transmit potato viruses. In glasshouse experiments, potato plants (cv. Désirée) infected with PLRV were grown in 30 cm pots containing compost treated at planting with carbamate (aldicarb or thiofanox) or organophosphorus (disulfoton or phorate) insecticides applied at approximately field rates. Groups of 10 apterous aphids from three clones of *M. persicae* representing each of three insecticide resistance variants S (susceptible), R_1 (moderately resistant) and R_2 (very resistant), were caged on separate leaves on each potato plant in bioassays performed 4-11 weeks after planting. In two experiment the cages were inspected after 24 h to record the number of settled aphids. The numbers of live aphids were recorded after 3 days and the transmission of PLRV by the survivors was tested on virus-sensitive indicator plants.

The five chemical treatments all decreased the ability of the aphids to settle, survive and reproduce (Table 3). However, the resistant clones were less affected, particularly by the organophosphorus insecticides, and produced more nymphs on treated plants than the susceptible clone.

In a third experiment, in which plants were bio-assayed 4, 5 and 7 weeks after treatment with aldicarb or disulfoton, about twice as many resistant and susceptible aphids survived 2 days exposure to treated plants and produced more nymphs, but after 4 days there was no difference in the survival of the three clones.

Transmission of PLRV by the surviving aphids was variable but the R_2 clone was usually a more effective vector than either the R_1 or the susceptible (Table 4).

(J. A. T. Woodford)

Table 3. Effects of carbamate and organophosphorus insecticides on susceptible (S) and resistant (R_1, R_2) *Myzus persicae*.

		% of aphids					
	Rate	Settled after 24 h			Dead after 72 h		
Treatment	(mg a.i./pot)	S	R_1	R_2	S	R_1	R_2
Carbamate							
Aldicarb	26	59	69	74	99	98	89
Aldicarb	13	58	75	74	96	90	76
Thiofanox	17	63	77	73	67	58	46
Organophosphorus							
Disulfoton	37	85	93	93	52	28	16
Phorate	51	84	94	91	63	16	12
Untreated	—	94	98	98	18	9	3

Table 4. Number of plants infected with PLRV by aphids in bioassays 6-10 weeks after treatment (Experiments 1 and 2) or 4-7 weeks after treatment (Experiment 3).

	Rate	Experiments 1 and 2			Experiment 3		
Treatment	(mg a.i./pot)	S	R_1	R_2	S	R_1	R_2
Aldicarb	26	2/20*	2/22	7/28	—	—	—
Aldicarb	13	4/26	6/27	7/32	1/20	1/27	0/27
Thiofanox	17	6/35	5/35	9/35	—	—	—
Disulfoton	37	5/34	5/35	10/35	0/30	4/30	3/30
Phorate	51	7/30	6/30	10/30	—	—	—
Untreated	—	9/33	10/34	8/32	3/30	6/31	1/30

*number infected/number tested

Transmission of viruses by trichodorid nematodes [PU 15(e)]

Tobacco rattle virus (TRV) transmitted by *Trichodorus* and *Paratrichodorus* nematodes is a cause of 'spraing' disease in potatoes (internal necrosis of tubers reducing their marketability), colour-break in bulbous ornamentals (lack of colour uniformity in the flowerheads reducing their commercial value) and substantial yield reductions in crops such as tobacco, pepper, and artichoke. Thirty different field associations involving trichodorids transmitting TRV have been described but only 10 are supported by adequate laboratory evidence. This is because of the widely acknowledged difficulties in using trichodorids in laboratory based virus transmission tests.

A laboratory micro-system that overcame many previous problems was established (*Ann. Rep. 1986*, 126) and used to examine specificity of acquisition, retention and transmission between different isolates of TRV

and species and populations of nematode. The system permitted accurate species identification, even of nematodes from populations comprised of several species, and serological characterisation of the transmitted virus (see Virology Report p. 189). This has enabled study of the specific natureof the field relationships between viruses and their nematode vectors at two sites. At an east Tayside site (Barry) each of 11 TRV isolates and at an east Fife site (Kinshaldy) 12 of 14 isolates transmitted by *P. pachydermus* were of the PRN serotype. Eight isolates transmitted by *T. cylindricus* from Barry are probably of a previously uncharacterised serotype and two isolates transmitted by *P. pachydermus* from Kinshaldy are of the spinach yellow mottle serotype. These preliminary results suggest that there is a close relationship between different species of trichodorid nematodes and serologically distinct isolates of TRV.

It has also been demonstrated that a virus-free population of *P. pachydermus* can acquire and transmit an isolate of TRV obtained from another population of *P. pachydermus* but that it cannot transmit a serologically unrelated isolate from *T. cylindricus*.

A further application of this laboratory system is to study the efficiency of acquisition and transmission of TRV. With naturally infected field populations of *P. pachydermus* from Barry and Kinshaldy approximately 10-15% were found to transmit virus. However, if the nematodes were first given access to TRV-infected plants in the laboratory the proportion subsequently transmitting virus was increased to 46 to 69%. These results indicate that *P. pachydermus* is potentially an efficient vector of its associated virus.

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

Transmission of serotypes of tomato black ring virus (TBRV) by *Longidorus attenuatus* [PU 15(e)]

It is becoming increasingly clear that the specificity of the relationship between nematode vectors and the viruses they transmit sometimes extends to populations and isolates. In laboratory tests a field population of *L. attenuatus* from England was found to be an effective vector of its associated TBRV with 57% of individual nematodes transmitting virus to *Petunia hybrida* bait plants. In contrast, with a field population of *L. attenuatus* obtained from Germany only 10% transmitted the virus. When the ability to acquire and transmit different virus isolates was tested it was found that a virus-free population of *L. attenuatus* from England was a more effective vector of four English isolates than of three German isolates (26-78% of nematodes transmitting compared to 1-15%).

These differences in transmissability were unexpected because all the isolates belong to the same 'English' serotype. Previously, vector specificity

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of nepovirus isolates has been correlated with their antigenic specificity and is therefore considered to be a property of the virus protein coat. A more detailed serological examination revealed small differences between the English and German isolates. One German and four English isolates were indistinguishable, but one of the German and one of the English isolates was distinguishable from these five and from each other. Consequently, differences in the efficiency of transmission of these isolates were not fully correlated with their serological characteristics and they must therefore differ in ways not revealed by our serological tests.

(D. J. F. Brown, A. F. Murant[1], D. L. Trudgill)

Structure and function of virus vector nematodes [PU 15(e)]

The oesophageal bulb of virus vector nematodes acts as a pump to withdraw plant cell constituents. It also contains the dorsal and subventral gland cells. Secretions from the former are injected into the root cell being fed upon and are responsible for inducing galling and the associated root cell modifications. The functioning of the oesophageal bulb, and especially the gland cells, is therefore of considerable interest and was observed in feeding *Xiphinema index* using video-enhanced contrast light microscopy. Changes in the plant root cells associated with feeding were also observed.

Nematodes fed on a column of progressively deeper cells close to the root-tip and in each the patterns of feeding behaviour and cell response were generally similar. Following penetration of the cell wall, secretions from the dorsal oesophageal gland cell were injected into the host cell; the secretions came, at least in part, from granules observed bursting close to the ducts in the dorsal gland cell. A short pause followed during which globules of fluid, thought to come from the subventral gland cells, passed backwards through the oesophageal-intestinal valve. There then followed three or four periods of oesophageal bulb pumping during which the cell contents were removed. Each period of pumping was separated by further injections of secretions from the dorsal gland cell which were introduced into the attacked cell with sufficient force to perturb the nucleus and nucleolus. These secretions were not, however, observed to be associated with further bursting of secretory granules in the gland ducts. The injection of saliva caused the cytoplasm surrounding the stylet tip to rapidly lose its structure and viscosity. With each injection of saliva this change progressively spread to the rest of the cytoplasm and the nucleus. As feeding progressed the cytoplasm and nucleoplasm were progressively ingested and the nucleolus progressively shrank until only a condensed residue remained. The plasmalemma and nuclear envelope were not dissolved. However, amyloplast membranes were dissolved and the starch granules released.

[1]Virology Department

This pattern of feeding was similar for cells in ungalled and galled root tips except that it took longer in the latter. Occasionally, feeding nematodes became inactive for *c.* 15 min immediately after their stylet tip had penetrated the next deeper cell. During each inactive period a plug was observed forming at the stylet tip, but it was uncertain whether secretions from the dorsal, ventral or both sets of gland cells were involved in its formation. The inactive periods were followed by extended periods of ingestion which were interspersed with short pauses during which dorsal gland cell secretions were again forceably injected. The plug interfered with the passage of these secretions. During the periods when feeding nematodes became inactive no changes were observed in the penetrated cell apart from a small clear zone developing in the cytoplasm surrounding the plug at the stylet tip.

(U. Wyss[1], W. M. Robertson, D. L. Trudgill)

The handling and extraction of virus-vector nematodes and field sampling to detect their associated viruses [PU 11(a)]

As part of a study on the handling and extraction of virus-vector nematodes, duplicated samples were collected on a grid pattern from eight fields in eastern Scotland. The nematodes were extracted from one sample whilst the other was bait-tested to detect nematode transmitted viruses. Trichodorid nematodes and tobacco rattle virus were present in six of the fields, in one field nematode-borne virus was detected in all of the 130 samples taken. *L. elongatus* was present at three sites, at two in association with tomato black ring virus and at the third site with raspberry ringpot virus. *X. diversicaudatum* was present together with arabis mosaic virus at one site. The viruses and their vectors each had aggregated distributions but there was no correlation between the numbers of nematodes and presence of virus. There was, however, a significant relationship in the presence or absence of the virus between pairs of samples taken at intervals up to 8 m apart. From these results a regular sampling pattern with 7 m centres is recommended for maximising detection of nematode transmitted viruses in fields in eastern Scotland.

(D. J. F. Brown, B. Boag)

Natural plant products as nematicides [PU 15(j)]

Studies over the past 3 years have shown that the sesquiterpenoid phytoalexin rishitin has nematode repellant and nematicidal properties. Rishitin was produced in potato tissue challenged by the bacterium *Erwinia carotovora*. *In vitro* studies showed that *Xiphinema diversicaudatum* became immobile within 10 min of immersion in 200 μg/ml rishin solution and died within 2 h. In 100 μg/ml solutions 90% of nematodes regained

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mobility if transferred into clean water within 3 h. The EC50s (median effective concentrations) of rishitin for nematodes after 10, 30 and 60 min immersion were 98, 33 and 18 μg/ml respectively. Additional studies have been undertaken examining the nematicidal potential of other naturally occuring compounds. Some of these compounds exhibit nematicidal activity, similar to that of rishitin against *X. diversicaudatum*, and greater than that of rishitin against *Globodera* spp.

(T. J. W. Alphey, W. M. Robertson, G. D. Lyon[1])

The predatory nematodes of the British Isles [PU 14(c)]

Several nematicides have been withdrawn from use in America due to their toxicity and concern for the environment. This has increased interest worldwide in biological methods of control. Samples from a previous survey of plant-parasitic nematodes of Great Britain were examined for predatory monochid nematodes as part of a study of natural control agents. Monochids were recorded from over 85% of the samples but numerically constituted only 2-3% of the nematodes present. The following species were recorded (the nine marked with an asterisk being reported for the first time from Great Britain):— *Anatonchus tridentatus*, **Truxonchus dolichurus*, **Mulveyellus vorax*, *Mononchus turbridgensis*, *M. niddensis*, *M. cristatus*, *M. truncatus*, *Micochus studeri*, **Coomansus parvus*, **C. arvensis*, *Clarkus papillatus*, *Prionchulus punctatus*, *P. muscorum*, *Mylonchulus brachyurus*, *M. sigmaturus*, **M. striatus*, **M. dentatus*, **M. agriculturae*, **M. vulvapapillatus*, **Paramylonchulus subterraneus*, *Iotonchus zechokkei* and *Choanolaimus psammphilis*. *A. tridentatus*, which were extracted from approximately 20% of the samples, was observed feeding on juveniles of *Longidorus elongatus* (see cover), a common migratory plant-parasitic nematode capable of damaging crops by both directly feeding on their roots and vectoring a range of pathogenic viruses.

(B. Boag, R. W. Small[2])

The mode of action of fungal endoparasites [PU 14(c)]

Fungi are known to be important natural control agents for the cereal cyst nematodes *Heterodera avenae*. Their mode of action and details of infection process were studied by scanning electron microscopy of 'cyro-polished', fully-frozen hydrated and freeze-dried specimens. Nematode females, even young ones containing no eggs, were sometimes colonised by *Nematophthora gynophylus*. In the early stages of infection the fungus was confined to the matrix between organs and cells. However invasion and destruction of the uterus soon followed.

The nematode egg parasite, *Verticillium chlamydosporium* was observed colonising the root around female nematodes. Once the female became

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infected any developing eggs that she contained were penetrated by appressoria and the egg contents destroyed. This resulted in cysts containing a mixture of eggs full of fungal hyphae and spores, and eggs containing fully developed second stage juveniles. Fungal infection stimulated the hatching of many juveniles in newly formed cysts which otherwise requires exposure to a period of chilling.

(L. V. Lopez Lorca[1], G. H. Duncan[2])

Control of nematode development [PU 15(i)]

Farmers frequently depend upon nematicidal chemicals for control of harmful nematodes. The presently available nematicides are targeted against cholinergic muscular junctions and are extremely toxic to mammals. Concern has also been expressed regarding their environmental effects. Consequently there is a growing need for new active compounds which are environmentally acceptable and less toxic. Research is underway to identify new physiological target sites in nematodes. Inital work (*Ann. Rep. 1986,* 127) identified immunoreactivity to 5-hydroxytryptamine, adrenocorticotrophic hormone, γ-aminobutyric acid and FMRF-amide in the free-living nematode *Goodeyus ulmi.* This work has now been extended to the plant parasitic nematode *Xiphinema index.* Techniques have been developed in immunofluorescent microscopy and in immunocyto chemistry at both light and electron microscopy level to identify the presence and the production sites of neuroactive compounds.

(T. J. W. Alphey, L. Leach[3])

Thermal-time requirement of the northern root-knot nematode *Meloidogyne hapla* [PU 14(c)]

Meloidogyne hapla is an important pest in many parts of Europe and commonly is transferred from one country to another on planting stocks. A collaborative investigation was made between Finland and Scotland to determine whether it could become established in either country. Laboratory studies at SCRI showed that 560 d°C above a threshold of 8.25°C was required for development from juvenile to juvenile but that maximum reproduction required more than 1120 d°C (*Ann. Rep. 1985,* 117).

Field plot trials confirmed the accuracy of these values. On perennial clover a small population was maintained in 1986 when the accumulated heat units were c.630 d°C above the 8.25°C threshold but no reproduction occurred on carrots where the accumulated heat units from germination were less than 600 d°C. In 1987 the accumulated heat units did not exceed 600°C with either crop and no reproduction was observed.

(A. Lahtinen[4], K. Tiilikkala[5], D. L. Trudgill)

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Advances in computer identification of nematodes [PU 14(c)]

Computer aided measurement and identification of plant-parasitic nematodes was first developed at this institute in 1981. However, the increased power and availability of modern desk top computers and the availability of programs produced by nematologists elsewhere has now required a re-assessment and upgrading of our original computer program. Using a BBC microcomputer, two disk drives and a digitising tablet three new programs based respectively on a matching procedure, a modification of Gower's coefficient and a statistical technique have been compared. The results from all three programs were statistically highly correlated in their ranking of species but the matching program took less than one third of the time required by the statistical program. Where mainframe computers are available the statistical program may be the best but for small desk-top computers the upgraded matching or modified Gower's coefficient programs would suffice.

All computer identification programs for nematodes have, to date, been written for migratory plant parasite species and none have been produced for the more economically important cyst nematodes. Identification of *Heterodera* and *Globodera* species utilises the characters of both cyst and juveniles whereas only characters from adult nematodes are required for migratory nematodes. A program developed jointly with IACR (RES) initially requires basic information about the cyst, which determines a subset of characters on which further information is required. Additional data is then requested on the juveniles. The process is repeated for a given number of cysts and the data matched with information on a reference data file for all species in that group. A ranked list of the most likely to least likely species is then produced.

(B. Boag, P. Smith[1], P. B. Topham[1], P. R. Burrows[2])

Control strategies for insect and mite pests of cane fruit [PU 9(b)]

Raspberry cane midge

Monitoring of emergence of adult, overwintered raspberry cane midge (*Resseliella theobaldi*) based on a simple model using meteorological data was reported last year (*Ann. Rep. 1986*, 130). This model has been further refined to take into consideration the direction and slope of plantations. Using observations from emergence data collected in Tayside by ESCA and East Anglia by ADAS in 1985 and 1986 the model was accurate to within 4 days of the observed emergence in seven out of eight sites.

Although this model can predict when adult midges are active and egg laying has started, the decision whether to apply an insecticide will depend on several other factors, including the presence or absence of natural splits in the bark of primocanes. This model can therefore be regarded as only a part of a more comprehensive monitoring programme.

(S. C. Gordon, I. A. Barrie[3])

[1]Data Processing Department
[2]IACR (Rothamsted Experimental Station)
[3]ADAS, MAFF, Wolverhampton

Clay-coloured weevil

The laboratory study on the fecundity and survival of adult clay-coloured weevils collected from the field in 1986 continued for a second year. In 1986, eggs were laid by 95% of the adult weevils. In late October the survivors (62% of the original population, *Ann. Rep. 1986,* 130) were transferred into polystyrene tubs containing moist sand and maintained overwinter at 4°C. Thirty-nine percent of the original population survived and in 1987 31% proceeded to lay further eggs. Although these weevils were fed on the same diet as in 1986, the number of eggs laid was considerably less, with an average of 89 eggs per weevil.

This study has shown that weevils can survive for long periods, at least in the laboratory where they are free from predatory pressures, and may explain why relatively large numbers of adult weevils can be found on raspberry plants in the early spring.

(S. C. Gordon, J. A. T. Woodford)

Double dart moth

In late April, 1987 two raspberry plantations of mixed cultivars displayed signs of severe bud damage (Fig. 2), similar to that previously reported as being caused by clay-coloured weevil adult feeding.

These plantations were monitored after dark (22.00-24.00 GMT) for weevil activity. Although weevils were present in one plantation, they

Figure 2

Raspberry cv. Glen Moy showing defoliation (left) caused by double dart moth larval feeding and uninfested plants (right) in same plantation.

could not be found at the second. However, small numbers (usually fewer than five larvae per plant) of a Noctuid moth larvae were found on the damaged canes. These larvae were collected and reared in the laboratory on fresh raspberry foliage. On pupation, they were transferred into containers containing moist sand. When the adults emerged they were identified as the double dart moth (*Graphiphora augur*).

At SCRI, the most severe bud damage was caused to the cultivars Glen Moy and Glen Prosen. The buds of these cultivars are slower to open in the spring than those of cv. Glen Clova. Although larvae of the double dart moth were observed feeding on expanding buds of Glen Clova, the damage was restricted to the small, expanding leaflets, whereas with the Glen Moy and Glen Prosen the centres of the buds were eaten and the buds were killed. Secondary and tertiary buds were stimulated into growth to give rise to replacement laterals. (Physiology and Crop Production Report p. 164.)

(S. C. Gordon)

Components and mechanisms of resistance to raspberry aphid *(Amphorophora idaei)* [PU 15(d)]

Although the use of raspberry cultivars resistant to strains of *A. idaei* is effective in controlling the spread of four viruses, the selection of further aphid strains may threaten this form of control. In order to provide a sound basis to counter this threat, a fundamental understanding of the mechanisms of resistance provided by different genes is needed. In 1987 experiments evaluated the levels and components of resistance to two strains of *A. idaei* in a range of raspberry cultivars, using field and laboratory aphid populations.

Table 5. Responses of *A. idaei* to susceptible and resistant raspberry cultivars

Cultivar	*Alate settling (40 h)*	*Nymph production (5 d)*	*% settling on excised leaves (48 h)*	
	Field population		*Strain 1*	*Strain 2*
Malling Jewel (susceptible)	337	492	100	97
Norfolk Giant (minor gene)	239	298	90	87
Malling Landmark (A_1 gene)	104	40	20	87
Glen Prosen (A_1 gene)	135	181	50	68
Joy (A_{10} gene)	128	6	20	40

The settling of *A. idaei* alates, using an artificially increased field population, was significantly reduced on cultivars containing the A_1 (Malling Landmark, Glen Prosen), the A_{10} (Joy) genes, and to a lesser extent, minor resistance genes (Norfolk Giant). Nymph deposition and development was also greatly reduced on Joy and Malling Landmark and was significantly less than on Glen Prosen and Norfolk Giant (Table 5). A 48 h laboratory bioassay, using floating excised leaves and laboratory-reared strains 1 and 2 of *A. idaei* produced results consistent with those of previous field and glasshouse experiments. The floating leaf test provides a more rapid alternative to conventional screening methods for identifying sources of resistance against both these common strains of *A. idaei*, as well as a useful bioassay system to test the effects of plant chemicals on settling and feeding behaviour.

(A. N. E. Birch, A. T. Jones[1])

Difference in raspberry cultivar tolerance of replanting problems [PU 9(c)]

When raspberry plantlets were planted in pots containing soil from a plantation heavily infested with *Pratylenchus penetrans* large differences were observed between cultivars in their growth response to a combined soil treatment of a nematicide (aldicarb) and a fungicide (benonyl) (*Ann. Rep. 1981*, 131). In untreated soil cv. Malling Jewel grew least well and cv. Glen Moy (clone 10.204) grew the best whereas in treated soil Malling Jewel showed the largest increase in growth and Glen Moy the smallest. The growth and response of cv. Glen Clova was intermediate.

To test whether these differences reflected differences in field tolerance of raspberry replanting disorders these three cultivars were planted at a site with a long history of raspberry production. Prior to planting plots were either treated in the autumn with dazomet (Basamid, 330 kg/ha) or at planting with aldicarb (Temik 10G, 6.6 kg a.i./ha). Because dazomet contains nitrogen and also helps mineralise soil nitrogen, additional non-dazomet plots also received an extra 60 kg/ha of NH_4NO_3 applied 1 month after planting.

Measurements of growth cane in the 2 years after treatment showed that dazomet had approximately doubled and aldicarb and the extra nitrogen had slightly increased the cane length per stool compared with the untreated (Table 6). However, the magnitude of the growth response was similar for all three cultivars and there was no evidence of tolerance differences. The results again demonstrate the huge growth response often achieved by pre-treating with dazomet at sites where raspberries are to be replanted immediately following the removal of the previous crop.

(D. L. Trudgill)

[1]Virology Department

Table 6. Mean length of raspberry cane per stool (cm) following soil treatments.

	Year 1			Year 2		
	Malling Jewel	Glen Clova	Glen Moy	Malling Jewel	Glen Clova	Glen Moy
Untreated	57	36	54	211	173	248
Extra N	77	52	62	204	212	225
Aldicarb	60	53	61	217	227	266
Dazomet	101	83	136	466	405	516

Mechanisms of resistance to root flies in brassicas [PU 15(d)]

Swede

Previous studies (*Ann. Rep. 1986,* 123) have shown that the most important components of root fly resistance in the SCRI cultivars Angus and Melfort are reduced plant attractiveness for oviposition and root factors which restrict larval feeding. In 1987, the influence of swede root chemical constituents on the movement of turnip root fly (*Delia floralis*) larvae was monitored in a laboratory bioassay for 2 h using a time-lapse video recording system. In two experiments 70% and 77% of larvae were attracted to the agar discs of susceptible-root diffusate compared with 30% and 23% to water control discs. There were no significant differences in the numbers of larvae attracted to either root cores or agar discs containing diffusate from susceptible or resistant swedes. These results indicate that *D. floralis* larvae are equally attracted to resistant and susceptible swede roots and their diffusates, and that resistance factors in swede roots are not detected by larvae until penetration and ingestion of the outer root tissue.

The depth of penetration by root fly larvae is an important factor in determining marketability and storage quality of both culinary and fodder swedes. Larval penetration was found to be significantly less on Angus and Melfort compared with root fly susceptible cultivars, and therefore the relationships between swede root dry matter content, tissue hardness and extent of root fly damage were investigated in a field experiment. Cores were taken from roots of two resistant (Angus, Melfort) and two susceptible (Doon Major, Sator Otofte) swede cultivars, grown without insecticides. Although significant correlations were found between dry matter content and tissue hardness ($r^2 = 0.47$), and also between dry matter content and root fly damage levels ($r^2 = 0.50$), the roots of Sator Otofte, the cultivar with the hardest roots, were extensively mined by both *D. floralis* and *D. radicum* (cabbage root fly). These results suggest that chemical factors which are associated with high dry matter and are localised in the outer root cortex of resistant swedes might be involved in deterring larval feeding.

(A. N. E. Birch, J. E. Bradshaw[1])

[1]Brassica Breeding Department

Fodder and oilseed rapes

In the UK, cabbage and turnip root flies (*D. floralis* and *D. radicum*) are increasing in pest status with the expanding area of oilseed rape. Besides having the potential to cause direct economic losses to oilseed and fodder rapes in northern Europe, root fly populations which build up on rape provide large pest reservoirs to attack other brassica crops later in the season. In 1987, glasshouse and laboratory experiments compared levels of susceptibility to *D. floralis* in one oilseed and four forage rapes, selected to give a range of seed glucosinolate levels.

Table 7. Susceptibility of rapes to turnip root fly attack

Cultivar	*Seed glucosinolates*	*Eggs/plant (OPT)*	*Larvae/root (RIT)*	*%Fresh wt loss*	
				Leaf	*Root*
Samo (FR)	Low	38	5	62	70
Darmor (OSR)	Low	69	19	66	70
Bonar (FR)	High	104	21	35	67
84411 (FR)	High	137	20	62	61
Lair (FR)	High	119	27	21	45

(FR) = forage rape; (OSR) = oilseed rape;
(OPT) = oviposition preference test
(RIT) = root inoculation test

In a five cultivar choice test for oviposition preference, significantly fewer *D. floralis* eggs were laid on cultivars Samo and Darmor (low seed glucosinolates) compared to Bonar, Lair and the selection 84411 (higher seed glucosinolates). In root inoculation tests (50 eggs/plant) unusually few larvae survived on Samo, even though damage to its roots was extensive. On Samo, Darmor and 84411 the severity of leaf wilting and relatively rapid plant death indicated a low level of damage tolerance. By comparison, the root systems of Lair and Bonar supported relatively high numbers of larvae without such adverse effects, indicating a higher level of tolerance. These results indicate that ovipositing *D. floralis* tend to select rape cultivars which can support relatively high numbers of larvae before plant death occurs. This selection behaviour by *D. floralis* is apparently associated with rapes which have increased root size and growth rates, as well as elevated seed glucosinolate levels.

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

An analysis of the cost of plant-parasitic damage to fodder brassicas [PU 10(c)]

Approximately 36,000 ha of fodder brassicas were grown in Scotland in 1985. A survey of 100 farms showed they were grown in soils containing a wide range of plant-parasitic nematodes. Numbers of nematodes were

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[2]Chemistry Department

generally considered to be below the threshold for damage in the majority of fields which had grown arable crops the previous year. To assess the damage done by nematodes nine field trials were made to test the yield response to soil treatments with the systemic insecticide/nematicide aldicarb (Temik 10G). The insecticidal effect of the aldicarb was nullified by treating the whole of the experimental area with an insecticide.

A mean yield increase of 21% was obtained with a range of 2 to 52% (Table 8). The three largest increases occured in exceptionally dry years and a more meaningful average increase is obtained when these extreme results are eliminated. It is difficult to accurately estimate the extent of losses nationally due to nematodes but extrapolating from these trials gives an average loss of 13.5 t/ha (15%) in the 20% of fodder brassicas grown after grass and 4.5 t/ha (5%) loss in those grown after arable crops. Assuming a mean value of £8.50/ton (range £2-£15) gives an aggregated loss of £1,930,000 m. Aldicarb also gives protection from root fly and swede midge damage but the cost of application and the possible environmental impact of the widespread use of aldicarb makes the cost/benefit analysis very questionable under most circumstances. However, where nematode populations are known to be large, and on light sandy soils where water stress is likely, nematode control may be justified. The most profitable long-term strategy for reducing losses due to plant-parasitic nematodes on a relatively low value crop such as fodder brassicas will be for the breeders to select cultivars tolerant of damage.

(B. Boag)

Table 8. Increase in fresh weight of fodder brassicas due to the application of nematicides

Year	Major nematode species	% increase
1975*	*Rotylenchus robustus*	52
1976*	*Longidorus elongatus*	36
1980	Range of species	3
1984*	*Longidorus elongatus*	36
1985	*Tylenchorhynchus dubuis*	29
1985	*Tylenchorhynchus dubuis*	15
1986	Range of species	2
1987	Range of species	11
1987	Range of species	3

Mean = 21

*Exceptionally dry years

PHYSIOLOGY AND CROP PRODUCTION

P. D. WAISTER

Though modelling of potato growth and development has already yielded results of potential value in field production, it has also highlighted some key developmental factors that must be better understood. The number of daughter tubers produced by a plant is a function of the number of stems and the number of tubers per stem, but for neither of these do we have adequate knowledge of the controlling processes. Data obtained this year gives further definition of the range of variation of these factors. Differences in tuber size within a crop are now known to be largely attributable to within-plant variation, which focusses attention on the origin and relative strengths of the tuber sinks, and hence on sucrose transport and partitioning. Evidence has been obtained of the key role of cell turgor in determining the uptake of sucrose in storage tissue and its subsequent conversion to starch.

Increasing concern about hazards from agrochemicals has led to the sudden banning of a key chemical, dinoseb, used as a desiccant for controlling and exploiting the vigour of the raspberry cv. Glen Clova, which now dominates Scottish production. Over the past 10 years many alternative chemicals have been examined, but no satisfactory substitute has been found. However some results concerning potential stop-gap treatments are reported from experiments financed by the HDC.

This Council has also given support to the search for alternative fruit crops, which has permitted the expansion of work on the most promising of these, the highbush blueberry.

POTATO

Potato: effects of water stress on leaf and crop growth [PU 5(a)]

The effects of water stress on rates of leaf appearance and growth and on the relation between interception of light and the production of dry matter were examined in an experiment in which drought was imposed from plant emergence by protecting the crop from rainfall using a mobile rain-shelter.

As in the previous year (*Ann. Rep. 1986*, 132), drought restricted canopy expansion and resulted in premature senescence. The rate of leaf extension can be related to soil mixture by:

$$Y = 3.01X^2 - 1.94X + 0.44$$

where Y is the rate of leaf extension expressed as a fraction of that of irrigated plants and X is the fraction of the total plant-extractable soil water remaining. In 1986, the rate of leaf appearance was greater in droughted than in irrigated plants. However in 1987 there was no significant difference between treatments. The difference between years is attributed to higher solar irradiance in 1986 increasing tissue temperatures of water stressed plants compared with irrigated ones, while in 1987 solar irradiance was lower and did not raise tissue temperatures in the droughted plants significantly above those of irrigated ones.

In both 1986 and 1987 the light conversion coefficient (LCC) in the irrigated control was 1.91 g/MJ. In the droughted treatment the LCC was unaffected by water stress until 50 days after emergence. Thereafter it declined with increasing stress. For the droughted treatments quadratic functions were fitted to the relation between dry matter accumulation and intercepted light for the droughted treatments. Derived values of LCC were related to the fraction of total plant-extractable soil water remaining in the rooting zone (X) by:

$$LCC = 1.21X + 1.06$$

with LCC constrained to a maximum of 1.91 g/MJ.

As in 1986, in early and mid-season, harvest indices were significantly greater in the droughted than in the irrigated treatment, but not at the final harvest. Tuber yield in the droughted treatment was 37% of that of the irrigated, as a result of the combined effects of lower tuber dry matter production (56%) and lower tuber water content (40%).

Functions derived from the experiments are being used to develop a model for potato growth constrained by water supply.

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

Potato: effects of drought on yield and dry matter concentration of tubers [PU 5(a)]

The effect of water supply on yield and tuber dry matter concentration ([DM]) was examined using nine cultivars grown under a range of water regimes in field experiments in 1986 and 1987. These cultivars were reputed to differ in drought tolerance. The slope of the relation between tuber yield of a particular cultivar and mean tuber yield for a treatment was greatest in Maris Piper (1.41) and least in Record (0.45). However stability, indicated by a low slope, was associated with low yields in general, and did not confer advantage over instability except under severe drought. Under conditions of slight to moderate drought less stable cultivars with higher potential yields are to be preferred.

Tubers grown during drought generally have higher [DM] values; however, the slopes of the relation between tuber [DM] in a particular cultivar and the mean tuber [DM] for a treatment indicated little cultivar

x water-supply interaction. The present work has not found clear differences within the cultivars examined in stability in tuber [DM] with changing water regime.

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

Potato: effects of waterlogging on growth and yield [PU 5(a)]

Last year seed tubers used in these studies had a natural burden of those micro-organisms that will cause rots under wet or anaerobic conditions. In this second year of study seed tubers were deliberately inoculated with a virulent strain of *Erwinia carotovora* so that plants should not survive the stress of waterlogging simply through having been uninfected.

Using tubers inoculated at low rates, and grown in a glasshouse, the effect of flooding for periods of 1 to 6 days at a time just before emergence again caused progressive reductions in levels of plant survival. Cv. Record was found to be more susceptible to *Erwinia* than was cv. Maris Piper but not more susceptible to waterlogging itself.

In a second experiment tubers of Record inoculated at high or low rates with *Erwinia* were supplied by M. C. M. Pérombelon[1], and the plants grown from these were either flooded at 10 days after emergence or were allowed to grow normally. Plants were harvested on five occasions at weekly intervals. Growth rates of the control plants with low and high levels of inoculum averaged 4.2 and 3.0 g/day respectively in the last 3 weeks of the experiment, while plants that had been flooded barely grew at all for the first 3 weeks and then averaged only 1.8 g/day over the last 2 weeks. The effect of flooding on yield of tubers was even more drastic. Control plants grown from tubers with low and high levels of *Erwinia* yielded 185 and 150 g/plant respectively over the period of the experiment. Plants that had been flooded yielded only 18 g/plant irrespective of the level of inoculation.

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

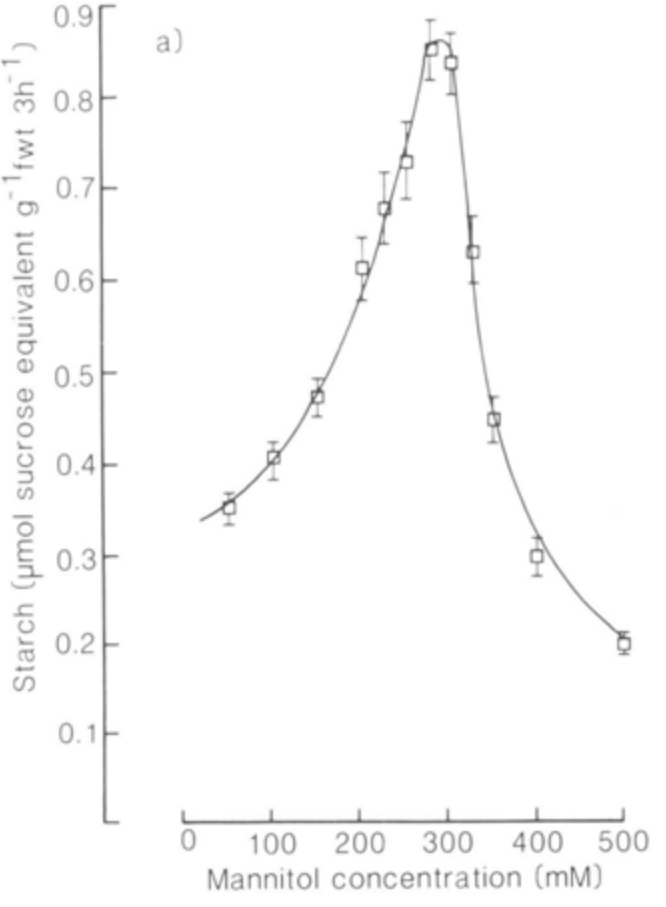
Potato: osmotic regulation of sucrose partitioning in tubers [PU 5(b)]

In an attempt to isolate the factors influencing the unloading of sucrose (*Ann. Rep. 1986*, 134) from the subsequent uptake and partitioning of sucrose by storage cells, experiments were begun *in vitro* using isolated tuber discs.

Sucrose uptake was poor in aqueous, buffered solutions. However, inclusion of mannitol as an osmoticum induced a large increase in both sucrose uptake *and* the conversion of sucrose to starch. Starch synthesis showed a distinct osmotic optimum at 300 mM mannitol and declined markedly on either side of this (Fig. 1) Subsequent experiments in which the effects of mannitol (a relatively non-permeant osmoticum) were

[1]Mycology and Bacteriology Department

Figure 1



Effect of mannitol concentration on sucrose to starch conversion by potato tuber discs.

compared with ethylene glycol (a permeant osmoticum) demonstrated that turgor pressure, rather than osmotic potential, had the dominant effect on sucrose partitioning, starch synthesis being maximised at very low, but positive (80 KPa) turgors, considerably lower than that of fresh tissue (320 KPa). Experiments with the metabolic inhibitor Carbonyl-cyanide-m-chlorophenyl-hydrazone (CCCP) demonstrated that low cell turgors enhanced active sucrose uptake at the plasmalemma, possibly by stimulation of a proton pump. In addition, CCCP virtually eliminated starch synthesis at all cell turgors. By contrast, the sulfhydryl compound Parachloromercuribenzene sulphonic acid (PCMBS) reduced sucrose uptake at the plasmalemma but did not affect the partitioning of sucrose to starch, a finding consistent with the view that this compound does not penetrate the plasmalemma and

inhibits predominantly the sucrose carrier. As with CCCP, inhibition of sucrose uptake by PCMBS was greatest at low cell turgors suggesting that the increased sucrose uptake at low turgor was by virtue of enhanced active and carrier-mediated transport.

Further experiments on the effects of altered turgor on sucrose partitioning revealed that whereas low turgor favoured the conversion of sucrose to starch, high cell turgors increased the amount of sucrose partitioned into the non-starch insoluble fraction. It now appears that carbon partitioning in potato tuber storage parenchyma is greatly influenced by diurnal changes in tissue water relations.

(K. J. Oparka, K. M. Wright)

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

A series of experiments was initiated to study the transport of sucrose between the phloem and storage cells of sprouting (source) and growing (sink) potato tubers. In isolated tuber discs the uptake of sucrose from buffered solutions containing between 0 and 100 mM sucrose (adjusted to 300 mM total external concentration with mannitol; see above) demonstrated biphasic kinetics in both growing and sprouting tubers. Apparent saturation kinetics were observed as the exogenous sucrose concentration was increased from 0 to 30 mM sucrose. These were superimposed on a non-saturable component which remained linear up to 300 mM sucrose. The conversion of sucrose to starch also demonstrated biphasic kinetics. At 50 mM exogenous sucrose 25% of the sucrose taken up by growing tubers was converted to starch, compared with only 3% in sprouting tubers. The osmotic optimum for sucrose uptake and starch synthesis, seen in growing tuber tissues, was not observed in sprouting tissues. A series of experiments with the inhibitors CCCP and PCMBS indicated further that the active, turgor-sensitive sucrose uptake component, found in growing tissue, was absent in sprouting tissue. A continuous study with tubers routinely sampled from a field crop showed that the transition from a turgor-sensitive, starch synthesising tissue to a turgor-insensitive non-starch synthesising tissue occurred gradually over the course of the growing season. Tubers examined at the end of the growing season, when the shoots had senesced, showed sucrose uptake kinetics more similar to those of sprouting tubers than those of rapidly-growing tubers.

(K. M. Wright, K. J. Oparka)

Potato: long-term metabolism of ^{14}C sugars in stored tubers [PU 5(b)]

^{14}C sucrose, ^{14}C glucose and ^{14}C fructose were introduced into potato tubers held at 10°C and the redistribution of label chased over a 65 day period in simulated storage. Respiratory losses were identical in all treatments, as was the partitioning of ^{14}C between soluble and insoluble forms. Sucrose was the predominant labelled sugar in the tubers after 20 h,

regardless of the original ^{14}C sugar introduced. Autoradiography provided evidence that this was then loaded and distributed through the tuber by a functional internal phloem network. Fructose represented a consistently low proportion of both the labelled and unlabelled sugars. By 21 days a considerable proportion of the soluble ^{14}C had been converted to starch (approx. 25% of the total tuber ^{14}C). Sprouts which formed on the tubers contained up to 6% of the total tuber ^{14}C but less than 0.2% of the tuber dry matter. The data indicated that the bulk of the translocated ^{14}C sucrose entered the symplast and exchanged slowly with the bulk of the sugars in the storage cell vacuoles.

(K. J. Oparka, H. V. Davies, D. A. M. Prior)

Potato: influence of nitrogen on assimilate partitioning [PU 5(b)]

A liquid culture system was developed for studying the effects of altered N nutrition on assimilate partitioning. Each liquid culture unit consisted of five replicate tanks supplied by a circulating nutrient solution. Single stems of cv. Maris Bard were grown in nutrient-deficient vermiculite before being transplanted into the culture units. The roots were submerged in the flowing nutrient solution while the tubers developed in vermiculite immediately above the culture solution. Continuous non-destructive measurements were made of root volume, tuber volume and whole-plant fresh weight under differing N regimes.

(N. T. Smoktunowicz[1], K. J. Oparka)

Potato: time lapse cine and video studies [PU 5(b)]

A system has been designed to record potato root growth and distribution, and stolon and tuber development, using time-lapse cine and video equipment for extended monitoring of growth below soil level, in darkness, while irradiating the canopy with fluorescent lighting. Using a Bolex cine camera coupled with a photographic flash transmitting through a double layer of Rank Strand green cinemoid, single exposures were recorded at 15 min intervals. The root system was also monitored in real time using an extended red Newvicon camera with continuous i.r. radiation supplied from i.r. diodes emitting at 880 nm. The experiments were set up under conditions of non-visible radiation using image intensifying goggles.

Stolons were shown to emerge in a basipetal sequence with first and second order stolons growing simultaneously. However, tubers did not form in the same sequence as the stolons, the fastest growing tuber on a stem bearing little relationship to stolon position.

(D. C. Gordon, K. J. Oparka)

[1]Research Student

Figure 2

Time lapse cine and video equipment filming and monitoring potato growth.

Potato: estimating tuber size distribution using image analysis [PU 5(d)]

Detailed information about the tuber distribution within a crop is essential to test the mathematical model that predicts graded yield and quickly to identify any crops that may deviate from the norm. At SCRI, tuber samples are usually graded into 5 mm intervals to obtain this information. However, for commercial crops this facility is rarely available. A photographic method of recording the sizes of tubers in a lifted sample has been developed, using standard panchromatic film and a 35 mm camera with flash gun. Both the camera lens and flash gun are covered with polaroid filters with the planes of polarisation positioned at right angles to each other to enhance the contrast between the tubers and background. The resultant negative is then analysed using a Quantimet image-analysis system. The technique eliminates tedious hand grading in the field or costly transport of tuber samples to a suitable grading centre. Alternative procedures that may eliminate the photographic stage are also being considered.

(B. Marshall, S. R. Verrall, P. Smith[1])

[1]Data Processing Department

Potato: seed production of cv. Record [PU 5(d)]

SCRI was contracted to measure and analyse the factors influencing size distribution in 45 commercial seed crops of cv. Record. The variation in seed yields between crops could be explained in terms of the variation in total yield and the number of daughter tubers produced. There was no evidence to suggest that the relative spread of tuber sizes was better in one crop than another nor between samples in the same field. This is consistent with previous findings where the major source of variation in tuber sizes lies within the plant. The relation between tuber number and stem density in these farm crops was much more variable than has previously been recorded in experiments. The causes of this variation will be the subject of future research. However, there was a suggestion that one cause was differences in the early growth rate of the crop.

(B. Marshall, S. R. Verrall, M. A. Kirkman[1])

Potato: nitrogen partitioning in early and maincrop cultivars [PU 5(e)]

Field-grown plants of cv. Maris Bard (early) produced as much total dry matter as cv. Maris Piper (maincrop) but partitioned dry matter differently. Earlier tuberisation and more rapid bulking in Maris Bard compared with Maris Piper was offset by an earlier decline in haulm dry weight as senescence occurred. Earlier senescence in Maris Bard was not associated with reduced N uptake compared with Maris Piper but with a switch in N partitioning to favour tuber growth rather than growth of stems and lamina. The primary cause of earlier senescence in Maris Bard is attributed to the inability of this cultivar to maintain a supply of young leaves through the development of leaf axillary buds and sympodial branching. Consequently protein and chlorophyll loss was more rapid in unshaded expanded leaves from the top of Maris Bard plants than in leaves taken from similar positions in the canopy of Maris Piper. Maintaining a high supply of nitrogen (total of 75 g/m^2 over the season) to the early cultivar reduced the rate of protein and chlorophyll loss in these leaves but did not prevent earlier senescence compared with plants of the maincrop cultivar receiving identical supplies of N.

(H. V. Davies, B. Marshall, H. A. Ross)

Potato: antioxidant metabolism and calcium related physiological disorders of tubers [PU 5(e)]

Potato genotypes differ in their susceptibility to the calcium related physiological disorder known as internal rust spot (IRS). A comparison of the calcium content (dry weight basis) of tuber perimedulla in a resistant cultivar Désirée, and a susceptible clone 10337 de40 showing severe symptoms of IRS, showed no significant difference between genotypes. The possibility of extremely localised calcium deficiency in10337 de40 was examined through the use of energy dispersive X-ray microanalysis. However, the calcium concentration was below the level of detection.

[1]Walkers Crisps Limited

The high lipolytic acyl hydrolase and lipoxygenase activities in potato tubers means that any disruption of membrane permeability caused by a deficiency of calcium may initiate a self-perpetuating peroxidation of lipid membranes. Determinations on the antioxidant status of Désirée and clone 10337 de40 failed to show significant differences in ascorbate and dehydroascorbate contents between genotypes. Although there was no measurable difference in the activity of ascorbate free radical reductase, the activity of dehydroascorbate reductase in Désirée was double that in clone 10337 de40. Similarly, the activity of the glutathione regenerating enzyme, glutathione reductase, was 50% higher in Désirée. The resistant cultivar also possessed a higher glutathione content and a higher ratio of reduced:oxidised glutathione. Of the other enzymic antioxidants analysed the activities of superoxide dismutase and peroxidase were 80 and 60% higher, respectively, in Désirée than in clone 10337 de40. In general, therefore, the antioxidant status is more favourable in Désirée.

Preliminary studies on the rate of efflux of previously loaded ^{14}C-sucrose from tuber perimedulla has indicated higher rates of loss from the IRS susceptible genotype. Inherent differences in membrane permeability properties may contribute to the degree of resistance to IRS in potato.

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

Potato: relation between water loss and hexose accumulation during storage [PU 5(f)]

To test the hypothesis that reducing sugar accumulation in stored potato tubers is related to the rate and extent of water loss and the subsequent need for turgor regulation, cv. Record was grown at three nitrogen levels (0, 175 and 350 kg/ha) and harvested on four occasions (100, 125, 137 and 146 days after planting). Tubers were stored at 10°C ± 1°C for up to 4 months and changes in water content and hexose and sucrose content monitored. At each harvest date the greatest water loss occurred in tubers from the high nitrogen treatment but this was not reflected in enhanced rates of hexose accumulation in storage. Irrespective of nitrogen application rate, more water was lost from, and more hexose accumulated in, tubers from earlier harvests. The higher levels of sucrose in tubers from these early harvests appear to contribute more to excessive hexose accumulation than the rate of water loss.

(D. L. Richardson)

Potato: relation between invertase activity and hexose accumulation in stored tubers [PU 5(f)]

Changes in the hexose and sucrose contents of tubers of cv. Record and SCRI clones 13737 1 and 13676 AB1 have been monitored in samples stored at 10°C and subsequently transferred to 3°C. Parallel determinations of basal

[1]Short-term Appointment

invertase activity (endogenous inhibitor present) and total invertase activity (invertase inhibitor destroyed) were made on the same tubers. Total invertase activity was extremely low in tubers freshly excised from the mother plant and there was no indication that considerable quantities of invertase inhibitor protein were present. Within 3 days after excision and storage at 10°C, total invertase activity increased more than fivefold in all genotypes and was accompanied by similar increases in hexose content. There was no evidence that this resulted from the hydrolysis of previously stored sucrose. Absolute hexose content changed very little during extended storage at 10°C, (up to 45 days) but remained lower in 13737 1 and 13676 AB1 than in Record (approximately half in the case of 13676 AB1). Invertase activity in 13676 AB1 was 50-80% lower than in Record. A smaller difference was observed between Record and clone 13737 1. Transfer of tubers to 3°C resulted in an increased hexose content of all genotypes but Record attained a hexose content of 60 mg/g d.wt. compared with a value of 25 for 13737 1 and 30 for 13676 AB1. This was reflected in the better processing potential (fry colour) of both clones compared with Record. At the same point in time invertase activity (determined at 30°C) in Record was 2.8 μg hexose/mg fr. wt./h, while the corresponding values for 13737 1 and 13676 AB1 were 1.4 and 1.3, respectively. Factors regulating the expression of invertase activity following the detachment of tubers from the mother plant are under investigation, as are the biochemical bases for genotypic variation in both invertase activity and hexose accumulation through other mechanisms.

(H. V. Davies, H. A. Ross, D. L. Richardson, G. R. Mackay[1])

Potato: effect of genotype on numbers of stems [PU 5(g)]

The number of above-ground stems produced by a seed tuber is a characteristic of the cultivar, but it can be modified by storage treatment. Stem production was examined in a range of cultivars from the breeding programmes of SCRI and Caithness Potato Breeders Ltd. Tubers were stored at 2°C after harvest in early October and batches of 40-45 mm tubers were planted in a glasshouse at 20°C on two occasions, November and April.

The first planting produced single-stemmed plants, but the onset and duration of emergence varied greatly between cultivars (Fig. 3). Tosca emerged over a period of 8 days, while Pentland Squire and Sherine took approximately 50 days because of wide ranges in times of dormancy break.

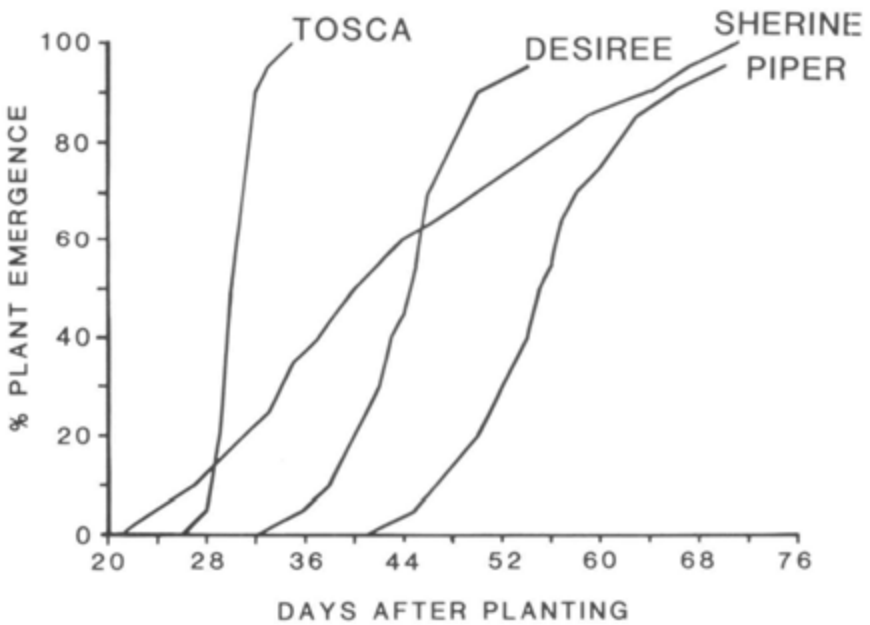
By the time of spring planting, apical dominance in the tubers had been lost, and emergence times and rates were similar between cultivars. The number of eyes present on a tuber was proportional to weight, and most cultivars had approximately the same proportion of sprouted eyes (50-60%). An exception was the cv. Alhamra, in which tubers had relatively

[1]Potato Breeding Department

few eyes, a high number of which were sprouted. Numbers of sprouted eyes were a poor guide to final numbers of above-ground stems as some sprouts failed to develop, and branching of the main stems occurred in some cultivars. The highest number of emerged stems was in Alhamra with 4.6 main stems and 4.0 below-ground lateral branches per plant.

(P. A. Gill, P. D. Waister)

Figure 3



Differences in plant emergence patterns for a selection of potato cultivars.

Potato: effect of seed origin on number of stems [PU 5(g)]

There are differences between cultivars in the numbers of stems produced from each seed tuber and their pattern of emergence. The length of time spent by a tuber in cold storage affects the progress of sprout development from the end of dormancy, through single-eyed apical dominance, to the multi-sprouted phase. However, it is not known to what extent seed tuber origin affects sprouting performance.

Samples of Désirée tubers (40-45 mm) were obtained in early October from several locations in Angus, Fife and Perthshire, and were stored at 2°C. Batches of tubers from each site were planted into compost at 20°C on two separate occasions, November and April.

At the first planting, the pattern of sprouting was similar for all batches, with single stems being produced from the apically dominant tubers. Complete emergence extended over a period of 25 days.

By April, all tubers were multi-sprouted and the time taken for plants to emerge had been reduced to an average of 7 days. The number of eyes from which above-ground stems arose was similar for all batches (3.3 per tuber), but the number of emerged stems varied from 3.4 to 6.0 per plant. Those with high numbers of stems had reached a multi-stem phase where below-ground branching of the main stem was occurring.

(P. A. Gill, P. D. Waister)

Estimating the yield of the national potato crop [PU 7(a)]

During 1983-85 a PMB grant helped us to develop techniques for estimating potential yield at sites throughout Great Britain. The current aim is to extend that work to produce useful forecasts of the actual final yield of the national crop at successive times during a growing season.

Estimations were made using husbandry details from the PMB and historical weather information from 1980-87. In addition, data from the local (Angus) and national surveys sponsored by the PMB between 1983 and 1985 were re-examined. Predicted yields were initially obtained by reducing the calculated potential yield by 1 t/ha for every 3.13 mm of water deficit experienced monthly. A second less empirical approach involves the use of a newly-developed model of water-constrained yield (the revised model) based on the SCRI model of potato growth and development and in which the rate of canopy expansion is modified by drought according to the fraction of available soil water remaining. In a second step, the effect of drought on the final dry matter concentration ([DM]) is being estimated.

An initial test of the revised model using data from the local surveys done in 1983-85 proved to be very encouraging; the model provided good estimates of intercepted solar radiation and the estimation of variable values of tuber [DM] further improved the estimates of yield. The revised model was run using appropriate variables for each PMB division for the years 1980 to 1987. The results were better than those provided by earlier procedures but there were still differences between predicted and observed yields in some years. The model of water-constrained yield is being developed further and the other causes of discrepancy are being examined.

(T. D. Heilbronn[1], D. K. L. MacKerron, R. A. Jefferies)

Potato: optimising seedrate [PU 7(a)]

An experiment involving twelve commercial cultivars (Cara, Désirée, Estima, King Edward, Kirsty, Maris Piper, Morene, Pentland Crown, Pentland Squire, Record, Romano and Wilja) planted at a range of spacings and mother tuber sizes has been used to test the mathematical model for optimising seedrate, developed in collaboration with ADAS (*Ann. Rep. 1986,* 138). On average, a fourfold increase in the weight of the mother tuber doubled the number of stems produced by the mother tuber.

[1]Short-term Appointment

This effect was consistent across all cultivars with the exception of Record which showed only half the increase in stem production. A detailed study of stem emergence and survival did not reveal any effect of competition on maximum stem number produced. For a given size of mother tuber, Romano produced the least stems closely followed by Morene and Record; King Edward was the most prolific followed by Kirsty and Maris Piper.

There was a close relation between the number of daughter tubers (>15 mm) produced and the stem density — which ranged from 6 to 60/m^2 over the treatments. In eight of the twelve cultivars the relation was very similar; at stem densities of 10, 30 and 50/m^2 tuber numbers ranged from 25 to 35, 60 and 75, and 90 to 110/m^2, respectively. The exceptions were King Edward which produced around 60 tubers/m^2 at a stem density of 10/m^2, and Wilja, Romano and Maris Piper which also produced above average numbers of tubers.

The variation in yield for a given stem density was much greater than the variation in tuber production. There appeared to be little or no effect of stem density on total yield above about 15 stems/m^2. This is consistent with earlier data collected by ADAS where stem density had to be as low as 5/m^2 for yields to fall to one half their maximum. There were no major differences between cultivars in this response.

Within an experiment stem density provides a unifying measure with which to explain variation in tuber number. It is now necessary to investigate the scale and causes of variation in this relation when other sites, weather patterns etc. are encountered.

(B. Marshall, H. Taylor)

PROTEIN SEED CROPS

EEC joint field bean project [PU 7(b)]

The final trial of the joint EEC 3 year project on field beans to compare the performance of 20 different lines and cultivars produced using several breeding methods was completed in 1987. The plant types included indeterminate, synthetics, early and late maturing. The analysis of the data covering all sites in Europe for 1987 is still to be completed. At SCRI the earliest maturing in all 3 years was Troy, 25 days earlier than Maris Bead, on average; and the latest maturing in 2 years and second latest in the other year was a line C, 4 days later than Maris Bead on average. The ranking by maturity was consistent over the 3 years but there was no strong correlation between the time to maturity and total yield. The two highest yielding lines — one never ranking lower than third and the other fourth in all three years — were both synthetics.

(B. Marshall, H. Taylor)

Field bean: cultivar evaluation [PU 7(b)]

Twenty eight breeding lines and cultivars continued to be assessed for their suitability for growing in a northern environment. In contrast to the previous year (*Ann. Rep. 1986*, 142) the plentiful supply of rain throughout the growing season favoured vegetative growth and delayed the timing and increased the range of maturation. Maris Bead reached maturity (75% black pods) on the 29 October, some 38 days later than the previous year and 17 days later than the wet year of 1985. Two and a half times the average rainfall in June and strong, gusting winds made lodging a serious problem. Some lines, with a determinate growth habit, were less prone to lodging and hence easier to harvest.

Table 1. Yield, maturity and degree of lodging of selected bean lines

	Maturity (− = days earlier)	Yield (t/ha)	Lodging (1 = none, 9 = severe)	
Ukko	−48	3.0	6.0	
*ETS 56/7/1	−38	3.8	4.5	
*Syn I/II	−37	3.9	6.2	
Tigo	−22	3.9	3.2	(determinate)
*WFTxETS 56/7/1	−10	3.4	7.2	
VSB 10064	−10	4.3	4.5	(determinate)
Maris Bead	0	4.0	5.5	
VSB 688	+10	4.9	6.8	
s.e.	3.2	0.51	0.39	
P	<0.001	0.004	<0.001	

* = SCRI/PBI line

ETS 56/7/1 is continuing in National List Trials in 1988. With appointment of a plant breeder responsible for field beans this work is now being transferred to the Plant Breeding Division.

(B. Marshall, H. Taylor)

Survival of winter beans [PU 7(d)]

Seventy two breeding lines from IPSR were sown at the end of October in 1986 to test overwinter survival. Mean air temperatures were above the 30 year average for SCRI in November, similar in December and 1.5°C below the average in January. In February, grass temperature fell below 0°C on 22 days and on one occasion reached a minimum of −11°C. The control cultivars Bourdon and Banner had 93 and 90% survival respectively, and in several of the breeding lines 100% survived. The lowest survival rate observed was 24%.

(H. Taylor, D. Bond[1])

[1]NSDO Ltd

Modelling nutrient uptake by root systems [PU 17(c)]

The rate at which a crop can extract nutrients from the soil is determined by the length (L) of root per unit volume of soil, and the rate (I) at which each unit length of root can absorb the nutrient from the soil solution. In effect, I and L determine the volume of soil that the plant exploits for a particular nutrient. Both are functions of the mean root radius (r,m). However, whereas I varies directly with r, L varies inversely with it. Using this conflicting relation it is possible to predict an optimal value of r, and consequently of I and L, at which the rate of nutrient uptake (U) by the whole root system contained within a volume of soil is maximised.

A simple mathematical model has revealed that U is maximised when L is $0.024/r^2m$. The values of L generated by this relation are considerably greater than those found for arable crops. The optimal values of I that were calculated were, however, not unrealistically high. It seems that the length and distribution of the root system in the soil imposes a more serious limitation on the attainment of maximal uptake rate by the crop than does the rate at which each root can absorb the nutrient from the soil. The rate of nutrient uptake by a crop would be improved more, therefore, by genetic modifications in the crop's root growth than in its ion transport characteristics. The latter, however, could be important in compensating for transient deficiencies in nutrient availability; this is the subject of current theoretical work.

(D. Robinson)

Maximum rates of nitrate uptake by single roots [PU 17(c)]

The roots of a nutrient deficient plant can absorb nutrients at rates far greater than when nutrients are abundantly and uniformly available. Such increases are seen when nutrients are re-supplied to a root system following a period of starvation and/or when nutrients are supplied locally to only a fraction (e.g. $<10\%$) of the whole root system. It is not known whether the roots of different species have the same capacity to increase their uptake rate, nor to what extent their actual uptake rates can approach a theoretical maximum value as determined by physical constraints such as ionic concentration and diffusivity.

The capacities of the roots of spring barley (*Hordeum vulgare* L. cv. Heriot), perennial ryegrass (*Lolium perenne* L. cv. S24) and potato (*Solanum tuberosum* L. cv. Russett Burbank) to absorb nitrate are being investigated. Plants were grown for 10-20 days in a nutrient solution containing nitrate at either a high (4 mol/m^3) or low (0.04 mol/m^3) concentration. The nitrate was depleted in ^{15}N (0.02 atom %) to minimise the background level of this isotope. A single intact root of each plant was isolated and supplied with ^{15}N-enriched (99 atom %) nitrate at 4 mol/m^3,

for 10 or 60 min, in order to measure respectively, gross and net rates of nitrate inflow. The low background of ^{15}N allowed the pulse of ^{15}N to be detected in the plant material; this would not have been possible had they contained ^{15}N at its natural abundance (0.37 atom %).

In ryegrass and barley the low N treatment induced 30% increases in both gross and net rates of nitrate inflow, compared with plants in the high N treatment; work on potato is still in progress. The fraction of the theoretical maximum inflow rate attained by the low N plants was double that of the high N plants. However, this fraction of maximum rate was still only 2% in the low N plants. This indicates that, in theory, considerable potential exists for genetic improvement of the capacity of plant roots to absorb nitrate although much more work is needed to understand the physiological, as opposed to physical, constraints of nutrient uptake by roots.

(D. Robinson, S. Buchan)

WEED INVESTIGATIONS

Weed seedbanks [PU 14(a)]

Weed seeds were extracted and identified from soil samples taken from 98 cereal fields in 1987. Preliminary analysis of the data has shown that a total of 43 species was represented, of which 10 occurred in at least 20% of fields and accounted for 82% of all seeds recorded. *Poa annua* L. was found in 90%, *Poa trivialis* L. and *Stellaria media* (L.) Vill. in at least 60% and *Spergula arvensis* L. and *Juncus* spp. in at least 40% of fields sampled. These species were also the most common in terms of total numbers of seeds recovered. Although the major species were similar to those recorded in an earlier survey of the weed seedbank of 100 swede fields, the range of species and the numbers of seeds found were much smaller, presumably reflecting differences in rotational practice and in efficiency of weed control in previous seasons. No viable seeds of *Avena fatua* L. or *Alopecurus myosuroides* Hudson were recovered from any of the soil samples taken from cereal fields. The minimum population detectable by the technique used was 1 seed/600 ml of soil analysed.

(H. M. Lawson, G. McN. Wright)

Weed control — information technology [PU 14(a)]

The HERBREX data-base was extended to include growth regulators and aquatic and industrial weed control. A second HERBREX bulletin *Herbicides for Barley Crops* was published in November 1987 by BCPC, using information extracted from the data-base.

A potato weed control package was extracted from HERBREX and made available on-line via AGVISER, which is an interactive viewdata system accessed via the telephone system.

In cooperation with Department of Mathematics and Computer Science, Dundee College of Technology, a pilot project examined the feasibility of matching data from a weed seedbank data-base with data in the HERBREX data-base. The objective was to select herbicide or other weed control strategies appropriate to the weed flora and soil characteristics of individual fields and crops. Results, using the dBASE III PLUS programming package were sufficiently promising to merit further investigation of this technique, using a wider range of weed, crop, soil and herbicide data.

In cooperation with DANI and Queen's University, Belfast, a pilot project has produced a problem-solving advisory package derived from HERBREX, using the MICROBIRD program. The user specifies crop type, a range of weed species and the required susceptibility ratings for these species, and is then directed to recommendations for the use of herbicides which meet the required criteria. The package is being made available to selected agricultural advisory officers in Northern Ireland for appraisal prior to further development.

(H. M. Lawson, P. Smith[1], G. McN. Wright)

Potato haulm desiccation [PU 14(b)]

Haulm desiccation by flame treatment has been suggested as an alternative to chemical desiccation. In a seed crop, desiccation requires treatment of actively growing foliage and stems, which are not suitable subjects for burning. However, chemical desiccation is not always fully effective and a supplementary flame treatment might be of value, especially if it removes the dead haulm and prevents it from interfering with the operation of harvesting machinery.

The incineration by propane-gas burner of desiccated stems remaining 2 weeks after routine application of diquat to a seed crop of cv. Maris Piper in late August proved unsuccessful. The stems were too wet to burn, despite prolonged treatment. Flame treatment had no adverse effect on the skin of tubers near the soil surface and there were no differences in yield or quality of tubers at harvest in comparison with diquat applied on its own. Evaluation of the herbicide cyanazine as a potential haulm desiccant for seed potato crops gave disappointing results. Speed of desiccation was very slow in comparison with diquat and was only marginally improved by the addition of mineral oil. There were no adverse effects on tuber yield or quality at harvest.

(H. M. Lawson, J. S. Wiseman)

Contamination of seed potato crops by herbicides [PU 14(b)]

Cereal herbicides which can affect potato tubers but give little or no visual indication of contamination of the foliage of seed crops pose problems for both farmers and crop inspectors. Potato plants grown in the field were

[1]Data Processing Department

contaminated at 60% canopy development 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). The latter treatment caused minor and temporary leaf rolling and distortion and both treatments slightly delayed further canopy development. Both treatments also reduced total yield of tubers by 8-9%, due mainly to a reduction in the proportion of ware sized tubers. However, 47% of tubers on plots treated with the formulated mixture had growth abnormalities which ranged from single growth cracks across the tuber to multiple cracks and malformation and covered all size grades. Only 1% of tubers had growth cracks on plots treated with metsulfuron-methyl alone and less than 1% were affected on untreated plots.

Applications of 1% normal dose of either treatment had no visible effects on crop foliage and caused no adverse effects on tuber yield or quality.

Stored tubers will be chitted and grown on to allow assessment of any continuing effects of treatment.

(H. M. Lawson, J. S. Wiseman)

FRUIT CROPS

Raspberry: studies on transport systems in ripening fruits [PU 6(a)]

Fluorescent dyes, $^{14}CO_2$-labelled bicarbonate and ^{45}Ca have been used to monitor the transport of solutes into raspberry drupelets at various stages of development. Radiolabelled calcium and the fluorescent dyes calcein, fluorescein and 8-anilino-1-naphthalene sulfonic acid were fed to berries through cut stalks, and $^{14}CO_2$ was fed to leaves adjacent to groups of berries with varying degrees of ripeness. Fluorescent dyes revealed a marked reduction in transport from berry plug to drupelets at the ripe stage and little or no movement into over-ripe berries. There was also a substantial reduction in the movement of calcium into berries between under-ripe and ripe stages but radiolabel was still detected in drupelets of over-ripe berries. Similarly, substantial quantities of assimilated ^{14}C was extracted from drupelets even at the over-ripe stage, although the ratio of ethanol soluble:insoluble ^{14}C showed a marked increase as ripening progressed. Radiolabelled ^{45}Ca and ^{14}C associated with drupelets of ripe and over-ripe berries may have been in the zone of occlusion that develops between drupelets and plug, rather than in the flesh of the drupelet. When ^{45}Ca was applied in surfactant to the exterior surface of the drupelets autoradiographs provided evidence of transport into the drupelets and into the stalk.

(H. V. Davies, D. T. Mason, K. J. Oparka)

Raspberry: pilot survey of yield components in commercial plantations [PU 6(b)]

The survey reported previously (*Ann. Rep. 1985*, 130; *Ann. Rep. 1986*, 143) was concluded. 1985 was a very wet season with vigorous cane growth which suffered considerable damage in the difficult harvest period. Residual effects were recorded in 1986 which, in spite of an unusually cool start to the growing season allowed plantations to recover. The weather in 1987 was more or less 'normal' throughout the growing and harvest season.

2. Raspberry yield component mean values (cv. Glen Clova)

	1985	1986	1987
Number of live canes/ha	50047	36261	42881
Number of laterals/cane	21.9	17.6	21.2
Number of fruit/lateral	7.0	6.0	6.2
Weighted mean berry wt (g)	3.55	3.42	3.50
Potential yield (t/fruiting ha)	25.7	13.0	18.9
Potential yield (t/field ha)	21.9	11.0	16.1
Harvested (t/field ha)	10.1	9.0	9.5
% harvested	48	82	61

These data will be considered in detail but it is clear that the greatest sources of variation in harvested yield derive from cane and picker management and their interaction with weather.

(M. R. Cormack, D. T. Mason)

Raspberry: mechanical harvesting [PU 6(c)]

The American Littau raspberry harvester which has been in use at SCRI since 1980 needs rows to be spaced wider (2.5 m) than is normal in Scottish plantations (1.8-2 m). The 'Harrier' raspberry harvester built by Pattenden Engineering of Kent, however, can work in the Scottish row spacings. The Littau machine uses vertical ranks of horizontal reciprocating nylon rods to shake fruit from the plants, and collects the fruit on spring-loaded, overlapping metal plates which damage young canes. The Harrier uses rubber covered metal fingers protruding from revolving and vibrating vertical metal cylinders (similar to those on the Agricultural Sciences machine used at SCRI prior to 1981 and on the SIAE rig) to shake off fruit, and a catching system designed to minimise damage to young canes. Much is known of the performance of the Littau machine, but no formal trials had been conducted with the Harrier. In order to provide information on which commercial judgements could be made, the performance of the Harrier was compared with that of the Littau machine and also with commercial hand pickers.

The economic assessment is not yet to hand, but in comparison with the Littau machine it was concluded that when vigour of shake is set at equivalent values, the Harrier will perform at a proficiency similar to that of the Littau harvester and the Harrier causes less damage to young canes than the Littau. The model of Harrier used, however, proved mechanically less reliable than the Littau.

The first fully biennial treatments in the plantation of 14/106 established in 1983 were picked by hand and by machine and compared with hand picked annual cropping. Hand picked ripe fruit from biennial plots cropped at 9.3 t/ha, machine picked biennial at 6.6 t/ha and the hand picked annual plots at 5.8 t/ha. The proportion of under-ripe fruit picked by machine from this selection was as usual very low (1.3%).

A collaborative project to test the combination of mechanical harvesting and biennial cropping on a commercial scale was started in 1983. A 3 ha field was planted with cv. Malling Orion (the only suitable cultivar available in sufficient numbers) at 2.5 m inter-row spacing to allow access to the Littau harvester. One third was to be harvested by hand annually, and each of the other one thirds by machine biennially in alternate years.

The first area to be picked by machine was harvested in its part-biennial phase in 1986 when a crop of 5.2 t/ha of ripe fruit was picked by machine and 7.2 t/ha from the hand picked annual area. In 1987 the other machine picked area in its part-biennial year yielded 2.7 t/ha compared to 4.4 t/ha from the hand picked annual area.

(M. R. Cormack)

Effect of machine harvesting on wounding and cane blight [PU 9(a)]

Machine harvester wounds on young raspberry canes are prone to infection by *Leptosphaeria coniothyrium* causing cane blight with death of canes in the fruiting year. The wounds made by the catching devices of the Pattenden 'Harrier' and the Littau harvester were compared in a risk assessment for cane blight in a replicated trial of cv. Malling Jewel.

After a single pass, the Littau catcher wounded 26.5% of the young canes, whereas the Pattenden wounded only 13.8%. After six passes during a 4 wk period, 51.5% of canes in plots harvested by the Littau had been wounded, but only 32.5% in the Pattenden plots. The wounds made by the Pattenden catcher averaged 32 mm in length, significantly shorter than those made by the Littau (57 mm). No differences in catcher wounds were found between harvesters when low, medium or high settings for shaking frequency of the picking heads were used.

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

[1]Mycology and Bacteriology Department

Raspberry: yield in the year after mechanical harvesting [PU 6(c)]

A plantation of the cultivars Malling Jewel and Glen Prosen, and selections 33R40 and 14/106, was planted in 1979 and since 1981 has been hand and machine harvested in years alternating with overall hand harvesting to assess residual effects of machine harvesting. In 1986 it was harvested by machine with hand picked controls, and in 1987 it was all hand picked. There were no differences recorded between the 1986 hand and machine picked plots possibly because inoculum levels of *Leptosphaeria coniothyrium* had not recovered from the effects of the 1982 to 1985 seasons (*Ann. Rep. 1986*, 145). The average yield of Malling Jewel was 6.5 t/ha, Glen Prosen 7.2 t/ha, 14/106 7.8 t/ha and 33R40 8.4 t/ha.

(M. R. Cormack)

Raspberry: National Fruit Trials [PU 6(d)]

The First Stage Trial planted in 1984, twin of one at Brogdale EHS in Kent, yielded its second full crop in 1987. An unusually severe attack of double dart moth (Zoology Report p. 137) affected some cultivars more than others. The larvae, which, like clay coloured weevil, feed on emerging greenery at bud burst, appeared to have an appetite for the 3655 series but hardly touched 3654/39 both from IHR (EM). Also susceptible to feeding were the SCRI selections 7515C5 and 72RG3, and cultivars Glen Moy and Leo; Glen Clova was very little affected and 7518E6 not at all. Cultivars vary in their ability to compensate and recover from early damage to buds and laterals so, although yield data were covaried with scores for damage, it is possible that these could be no more representative of performance than the recorded data. However, although yields were reasonable, ranging from 10 to 17 t/ha, it was noticeable that the cultivars most affected by moth were at the lower end of the scale.

Of the leading selections, 7518E6 with its large fruit (5.76 g/berry) produced the heaviest yield (17 t/ha), and the promising late 3655/48 which cropped at 11 t/ha (5.07 g/berry) despite suffering the most severe attack by the moth may well have cropped around the covaried figure of 15 t/ha as it did in 1986 (16 t/ha). The main control Glen Clova produced nearly 13 t/ha.

(M. R. Cormack)

Raspberry — alternative methods of cane vigour control [PU 6(d)]

Of a wide range of potential treatments screened during 1987, only sulphuric acid and flame cultivation gave adequate desiccation of first-flush canes. Both treatments also injured fruiting canes and reduced yield of fruit at high rates of application. Further work is needed to determine whether or not an adequate margin of safety can be established to the rates, application techniques and timing needed for effective desiccation.

Chemical treatments found to give inadequate desiccation, even at very high rates of application, included paraquat, diquat, tar oil, cyanazine and ammonium nitrate.

(H. M. Lawson, J. S. Wiseman, G. McN. Wright)

Raspberry — effects of bud damage by double dart moth *(Graphiphora augur Fabr.)*in the presence or absence of cane vigour control

An area of cv. Glen Moy devoted to an experiment on cane vigour control was severely affected in patches by larvae of the double dart moth in 1987. It was possible to compare plots on which >90% of primary laterals had suffered complete removal of buds against adjacent unaffected plots. Both groups included plots which had had the first flush of young canes either removed at 15 cm high or left untreated. Damaged canes produced secondary laterals which fruited normally, Overall, cane vigour control increased yield per metre length of fruiting cane by 36%, while severe injury by double dart moth reduced yield by 37%. These differences were due mainly to differences in numbers of berries produced. Berry size was not significantly affected. Cane vigour control had no effect on mean harvest date, but insect damage delayed it by 11 days. There was no evidence of significant interaction between cane vigour control and insect damage in any of the measurements recorded. In commercial practice the yield losses due to insect damage would have been considerably greater, since fruit ripening after the main harvesting period of the plantation would not have been picked.

(H. M. Lawson, J. S. Wiseman, S. C. Gordon[1])

Highbush blueberry [PU 6(d)]

The beneficial effects of irrigation on blueberries have been reported in previous Annual Reports. Yields in 1987 were exceptionally high, Bluecrop producing 24.4 t/ha, over 7 kg per bush, from irrigated and 15.7 t/ha from unirrigated plots and Berkeley 24.7 and 16.5 t/ha respectively. Fruit size was similar for both cultivars, with irrigated berries having an average weight of 1.41 g and unirrigated 1.12 g.

The relatively long establishment period of highbush blueberries is a disincentive to potential growers. In an attempt to reduce this by increasing soil temperatures, the cultivars, Bluecrop, Berkeley and Bluehaven were planted through either clear or black polythene or into open soil in 1981. Clear polythene plots were pretreated with dazomet to control weeds. Initial growth was improved by both clear and black polythene. The clear polythene, which deteriorated quickly, was replaced each year until 1985 and then removed. The original black polythene is still intact. The polythene covered plots produced an average of about 6t/ha of fruit in 1987 and the untreated plots about 1 t/ha. Bluecrop produced the heaviest yields.

(M. R. Cormack)

[1]Zoology Department

Blackberry and novel fruit crops [PU 6(d)]

Blackberry and hybrid *Rubus* cultivars are under observation in a plantation of single row plots. Ashton Cross and Bedford Giant have consistently outcropped other candidates. They produced over 12 t/ha in 1986 while Oregon Thornless, Tayberry and 126RA8 bore 3 t/ha crops. In 1987, Bedford Giant yielded 22 t/ha, Ashton Cross 16 t/ha, Tayberry 8 t/ha and Oregon Thornless and Chehalem 5 t/ha. The more recently planted Tummelberry (1985) produced 3 t/ha of very large fruit (7.9 g per berry).

In a biennial cropping trial planted in 1985, Ashton Cross in its part-biennial year produced 14 t/ha compared with 11 t/ha from the annual control and Tayberry produced 1.5 t/ha and 1.8 t/ha respectively.

(M. R. Cormack)

CHEMISTRY

M. J. ALLISON

Early in the year, three of the staff transferred from MISR to SCRI were allocated to the Chemistry Department and will be responsible for the following capital equipment which was acquired during the year: a gas chromatograph interfaced to a mass spectrometer (Kratos Ltd), a plasma emission spectrometer (ARL laboratories), a ^{15}N stable isotope mass spectrometer (Europa Scientific Laboratories) and a nitrogen analysis system (Kjeltec). Laboratories in the new building block were adapted to meet the requirements for these machines, and the potential for analytical work in the Department has thus expanded to include a wide array of services which will be available when the new laboratory block and this equipment are commissioned.

It was decided because of recent financial constraints to give priority to chemical analyses that can earn external funds, for example, glucosinolate analysis of oilseed rape seed is now available to farmers at a charge of £33 per sample. Analyses utilising the new machines will also be for sale, in addition to servicing the Institute's needs. As part of the Department's efforts to acquire external funding, a software package (currently called 'Prospector') was devised jointly with J. W. McNicol[1] and was offered for sale. Pacific Scientific Inc. showed interest in marketing Prospector, and a contract setting out the conditions for marketing this product worldwide is being finalised. A refurbished version of the Comparamill is also for sale and this machine attracted keen interest from both scientists and established companies when it was demonstrated during British laboratory week at Olympia, London.

Routine service analyses completed during the year included total glucosinolates in brassica (795 samples by HPLC and a glucose release method), thiocyanates in brassica (360 samples), digestibility of brassica (490 samples), SMCO in brassica (700 samples), micromalts of barley (700 samples), anthocyanins in black currants (224 samples) and sugars by HPLC in potato tubers and swede bulbs (440 and 40 samples respectively).

Other work included a computer program written to control electrical pulsing so that large DNA molecules could be separated on a pulsed field inversion electrophoretic apparatus. This system was used successfully by a visiting worker who was able to separate clearly concatamers of lambda

[1]Data Processing Department

phage DNA up to 800 K base pairs in size on our home made system. Investigations were made into the chemical factors in black currant buds relating to gall mite resistance and mono- and sesquiterpenes were successfully separated from the surfaces of black currant buds and leaves using a capillary gas chromatograph. Previous work indicates that one of the black currant mono-terpenes is involved in gall mite resistance.

Prospector — a principal components package for NIR spectra

The NIR plus principal components analysis package developed over the last 5 years at SCRI was completed this year when the routine for individual spectral responses was incorporated into the regression models for prediction. The package was then rewritten to run on an IBM PC and agreement was reached with Pacific Scientific Inc. of Silver Springs, Maryland, USA, to market this package worldwide.

This software package can be used to derive twenty principal components of 100 spectra, each consisting of 700 data points all within 1 hour on the computer. In addition to the derivation of regression models which predict composition on the basis of principal components, the package has extensive facilities to validate these models and to identify the underlying factors which affect the accuracy of prediction. Individual samples may also be examined for unusual spectral characteristics which may affect prediction accuracy.

(I. A. Cowe, D. C. Cuthbertson)

The use of HPLC as a rapid screening method for potato glycoalkaloids [PU 1(f)]

A HPLC method for the estimation of the glycoalkaloid content (TGA) of potato tubers has proved to be quicker, more reliable and less labour intensive than existing methods. Estimations of TGA using the HPLC technique correlated well with results from an ELISA test and a dye binding method. These correlations were obtained for ten samples evenly spread over a narrow range (4 to 23 mg TGA/100 g fresh weight).

			r. value
Dye binding	v	ELISA*	0.87
Dye binding	v	HPLC	0.92
ELISA	v	HPLC	0.91
Mean: Dye binding test and ELISA	v	HPLC	0.94

*See *Ann. Rep. 1985*, 139.

An advantage of the HPLC method is that the glycoalkaloids e.g. ∝-solanine and ∝-chaconine can be estimated separately.

(H. Bain)

Electropulse — a computer program for the control of a pulsed field inversion electrophoretic apparatus [PU 2(c)]

A computer program was written for a BBC B-plus microcomputer which allowed an electrical field to be inverted for varying time intervals in a pulsed field electrophoretic apparatus. This system was successfully applied by A. Burns[1] who separated concatamers of lambda phage DNA ranging from 50 K to 800 K base pairs in length. Separations of large DNA molecules are required for genetic mapping studies using restriction fragment polymorphisms.

(D. C. Cuthbertson)

Milling Energy estimations using the refurbished Comparamill [PU 2(f)]

Measurements of milling energy using an inert uniformly-shaped inorganic standard showed that the average error in repeated milling of similar samples was c. 1 joule. This error increased to about 5 joules when samples of barley were used, indicating that sample variability and sampling error were the main sources of variability and so improvements in the Comparamill hardware would not significantly increase the accuracy of the estimations.

An effort was made to assess the effects of moisture content and nitrogen on milling energy estimates. Using samples kindly provided by local maltsters, it was established that the Comparamill could mill samples up to at least 22% moisture content. Increases in moisture content from 10 to 18% added approximately 24 joules for each percentage rise in moisture. Above 18% the increase was greater and non-linear. For malting cultivars the nitrogen content (which ranged from 1.2 to 1.8%) did not correlate highly with milling energy. The results suggest that a correction for moisture could be made at least for some of the moisture range with no need for a nitrogen correction over the narrow range tested.

Preliminary work in collaboration with J. S. Swanston[2] was done on the effect of grain maturity on milling energy. Three cultivars were sampled in the field up to 1 month before harvest. During this time grain filling proceeded and the moisture content decreased. The ranking order of the cultivars in milling energy remained the same at each sampling date. Despite the fact that milling energy increased as the grain filling proceeded, the results indicated that endosperms can be screened for rapid malting potential before harvest, thus avoiding wasted effort in harvesting and cleaning unsuitable breeding material.

(I. A. Cowe, K. Taylor)

[1]Visiting Worker
[2]Cereal Breeding Department

Seasonal variation in the S-methyl cysteine sulphoxide (SMCO) content of glasshouse grown forage rape [PU 4(1)]

In collaboration with the Brassica Breeding Department the SMCO content was determined for samples from two cultivars and one breeding line of forage rape harvested at weekly intervals over a period of 9 to 22 weeks after sowing. Comparatively little difference in SMCO concentrations was observed between the two cultivars and the breeding line studied but SMCO concentration varied significantly with time of harvest. A peak concentration of approximately 0.8 g/100 g DM was found between weeks 12-14 after sowing and thereafter the concentration declined to a minimum of around 0.3 g/100 g DM at week 19. Over the next 2 weeks SMCO concentration again increased rapidly to between 0.6 and 0.7 g/100 g DM. Clearly further investigations are required to determine whether the observed trends may be related to specific growth stages and as to whether the observed period of minimum SMCO concentration can be utilised to minimise the SMCO intake under field conditions.

An HPLC plus glucose release method for the estimation of glucosinolates in rape seed compared favourably with results on subsamples of the rapes analysed at three other laboratories. In our method the total glucosinolate assay is based on that developed at FRI, but we determine glucose by reduction of a neocuproine reagent in an autoanalyser system.

(D. W. Griffiths)

Scanning electron microscopy of starch granules

Further studies on the morphology of gelatinised starch granules was carried out by scanning electron microscopy of frozen-hydrated samples (*Ann. Rep. 1986*, 150). Starch granules in solutions containing urea guanidinium chloride or ascorbic acid were more spherical after swelling than those in a water : starch system.

Type A granules of both waxy and normal barley starches buckled during gelatinisation but the former showed much more swelling. This buckling would appear not to be due to amylose content (2% in waxy starch and 25% in normal) but to amylopectin.

(R. Tester[1], G. H. Duncan[2])

[1]Department of Bioscience and Biotechnology, University of Strathclyde

[2]Virology Department

DATA PROCESSING

The formation of the Scottish Agricultural Statistical Service in April 1987 deprived the Data Processing Department of any remit for statistics. This, together with the retirement of P. B. Topham, who had been Head of Data Processing since the creation of SCRI 8 years ago created the need for a considerable degree of reorganisation within the Department. In addition, two major planning exercises had to be undertaken.

Physical transfer of the Data Processing Department to the new laboratory block extension made some re-wiring of the Edinburgh Multi-Access System (EMAS) terminals inevitable. The existing wiring configuration was reviewed and it was decided to re-wire the entire site using 6 wires per connection in accordance with EUCS recommendations and to introduce a third PAD allowing any 12 from 48 simultaneous connections to EMAS. The first phase of the re-wiring will be carried out in 1988.

In the second planning exercise, the Department participated in the first comprehensive review of computing conducted by the Computing Policy Sub-Group of the Joint Management Board (JMB). Survey data from other SARIs and SACs were collected via electronic mail on EMAS in an agreed format suitable for input into the popular microcomputer program dBASEIII. This was made possible due to the cooperation of the Computer Liaison Group. The data covered staffing levels and costs, details of installed hardware and commercial software purchased. Reports were compiled from the database files and used by the JMB in its decision making. The database is to be updated annually henceforth.

Computing Services

The number of EMAS users increased slightly (2%) (Table 1), but many numbers were re-allocated to accommodate staff changes. Mainframe usage increased by 7%, which was less than the percentage increase in previous years. However, microcomputers are ever more powerful and capable of taking on some of the work formerly sent to the mainframe.

Two IBM compatible micros were purchased, with 20 Megabyte hard disks, and one IBM XT. Most scientific departments now have at least one microcomputer with a hard disk at their disposal. Some new scientific instruments now come with microcomputers as controllers. In some cases these microcomputers can be run as stand-alone machines, making it difficult to decide whether they should be classified as computing or scientific equipment.

Table 1

Mainframe usage 1987

	Users	Logons	% Logons
Brassica Breeding	6	252	2.71
Cereal Breeding	6	793	8.54
Chemistry	7	436	4.69
Data Processing	10	1755	18.89
Estate	1	35	0.38
Information Services	3	355	3.82
Mycology and Bacteriology	11	552	5.94
Physiology and Crop Production	22	2229	23.99
Potato Breeding	14	1570	16.90
Soft Fruit Breeding	3	188	2.02
Tissue Culture	1	89	0.96
Virology	5	296	3.19
Zoology	12	741	7.98
	101	9291	100.00

There was a good attendance at the spring EMAS course, held in-house, as former MISR staff took the chance to familiarise themselves with our computing facilities.

The biological sciences user support team from EUCS gave a seminar on electronic mail as part of an introductory visit. They are the first line of contact within EUCS for user problems that are outwith the immediate control of the Data Processing Department staff. Close ties should ensure that rapid solutions to problems can be found.

Electronic Mail and Telex use continued to increase. Significant reductions in on-line charges for connect time and system storage have been achieved through the use of the communications package 'Headline'. This permits the off-line preparation and printing of messages and the use of automatic access commands, thus minimising the time spent connected to British Telecom Gold.

(R. J. Clark)

Data Management

The subject access provisions of the Data Protection Act 1984 came into effect in November. Procedures for dealing with requests were introduced with the aid of forms designed and supplied by the Data Protection Co-ordinator, H. J. V. Gledhill in AFRC Central Office.

The HERBREX (herbicide information system) was publicly demonstrated twice, at Bonar Hall, Dundee, for the Crop Protection in Northern Britain Conference, and at the BCPC Weeds Conference in Brighton.

A seminar was held demonstrating dBASEIII on an Apricot Xen, using the Brassica Genetics Programme developed with J. R. T. Hodgkin[1]. This stimulated interest in other departments and resulted in the development of a prototype database management system for the Cereal Breeding Department and another for the Soft Fruit Breeding Department.

A database file was used to store the internal telephone directory for the Institute. The directory can be published in departmental form or alphabetically by surname. Other lists sorted by telephone number can be produced to suit the Institute Engineer.

Software

The plant breeders' package CHIP was transferred to EMAS-A and the code was tightened up to comply more fully with the manual. Further work was done on transferring the package to a microcomputer under MS-DOS. Because unexplained program errors occurred when using the Microsoft Fortran compiler the work was continued using the Prospero ProFortran compiler. It was discovered that the whole of CHIP could not be mounted at once. Further investigation is needed to decide on the optimal grouping of the CHIP directives.

The Comparamill software was extended to incorporate prerecorded sample weights. It was also made more 'presentable' to help generate more interest at demonstrations.

Spreadsheets were increasingly used for simple calculations and tabulations of data. The setting up of a spreadsheet template is faster than writing a tailored program for the user, but it does put more responsibility on the user because of the lack of on-screen prompts.

Most 'in-house' software is still in UCSD Pascal, upgraded this year to the Pecan Power System version. The user of UCSD has had a similar environment independent of the micro-computer being used, e.g. Apple II, Apricot, Superbrain and IBM. In cases where the portability of the software across micro/mainframe machines is considered to be of high importance it was decided to use FORTRAN77. The feasibility of using the UCSD FORTRAN77 compiler and the interfaces now available between the UCSD and MS-DOS operating system are being investigated.

(R. Kidger)

Funding from the Scottish Development Agency's contribution to the 'Dundee Project' facilitated an assessment of the commercial potential for acquiring, packaging and marketing data from agricultural research, in particular through information technology (IT).

[1]Brassica Breeding Department

Potential users of this type of packaged information were divided into three groups: research, advisory and educational organisations; contractors, chemical companies etc.; and farmers. The first group felt there was an increasing requirement for government sponsored R & D findings to be made available through computers to the farming industry. The specialists in the second group have an increasing demand for comprehensive, easily accessible information packages that support decision making in crop management. This group also has the necessary experience to use such computer based systems. The majority of the third group felt they had little time to devote to hands-on experience of computerised information and preferred to access such knowledge through specialists.

A survey of the information sources currently used to provide advice to the farming industry covered existing arable computer packages and software companies, private and government sponsored advisory services, and viewdata systems. Sources of information which could extend the range of IT aided advisory systems were also highlighted. In general it was concluded that the number of IT products in agriculture is surprisingly small, with the exception of floppy disk based accounting packages, and is widely dispersed in respect both of the area of application and means of communication. The most successful means of communication used at present involves an intermediary with access to computer hardware and software. Typically the intermediary will be an advisor, crop consultant or commercial company. The communications between the intermediary and farmer are most likely to be verbal or written rather than electronic. However there was a strong feeling throughout the industry that IT would be an integral component of agriculture within the next few years. The report of the assessment team concludes with a list of detailed recommendations which should be carried out to ensure that the role of research institutes in this development will be both active and effective.

(J. W. McNicol[1], B. Marshall[2], R. Thompson[3], P. D. Waister[2])

Image analysis

The major routine use of the Quantimet 900 image analyser was for measurement of potato tuber dimensions (length, breadth, area) from photographs. These measurements were then used to predict grade size as sorted by a mechanical grader, to support modelling of the growth of the potato crop.

Several new applications were developed for the image analyser. Plant root lengths were measured from contact prints using fields of view each 70 by 50 mm, giving the best compromise between measurement area and magnification. Roots vary in thickness, so the detected image is 'skeletonised' prior to measurement. The roots must be painstakingly separated and extended before measurement. (with D. Robinson[2] and S. Buchan[2]).

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[1]SASS
[2]Physiology and Crop Production Department
[3]Honorary Research Associate

Aphid behavioural responses to chemicals applied to their host plant were examined using time-lapse video-recording. Potato leaves were treated with two chemicals. Aphids were subsequently exposed to these leaves (and an untreated control) by caging them in plastic cells on the adaxial leaf surfaces. Two techniques to measure aphid activity during recordings of up to 18h of three cells were compared using playback at 6 times normal speed. For the first, the number of aphids in movement in the first 20s (i.e. 3.3 s elapsed time) of each minute was counted visually. For the second, the image analyser local spot detector was used to identify aphids and the detected image was stored. After 1.5 s a second image was digitised, aphids were again detected, and the differences between the two stored images were interpreted as aphid movement in the period sampled. The measurements showed cyclical changes in aphid activity, and differences between treatments. There was no evidence of any difference in the number of aphid movements between the two techniques. The visual method required considerable skill and effort to obtain accurate measurements, compared with the image analyser technique (with J. A. T. Woodford[1]).

Quantitative measurements of chemotactic behaviour of fly larvae exposed to chemical substances were made from photographs. Larvae were placed at the centre of a Petri dish, and paper strips holding the experimental substances in ethanol solution and the control (pure ethanol) were placed in alternate quadrants. The spot detector was used to count larvae in five annuli in each quadrant of the dish. Bubbles were excluded by setting a minimum area. The method was more rapid and convenient than a manual method (with A. N. E. Birch[1]).

The relationship between chemical composition of leaf surface waxes and mildew susceptibility of different spring barley cultivars was studied using the image analyser to ensure consistent measurements of the area of mildew lesions. Individual leaves were illuminated with polarised light to give the best contrast. Lesion number was also used as a measure of the amount of infection, and was most highly correlated with lesion area on those cultivars on which the mildew lesion had a distinct margin (with A. C. Newton[2]).

Programming

In response to user requests, modifications were made to the Variety Trial Program to allow an option for an additional data order which entailed changes to the procedures for data entry and analysis (with J. W. McNicol[3]).

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[1]Zoology Department
[2]Mycology and Bacteriology Department
[3]SASS

The nematode identification program (NEMIDS) takes digitiser measurements of nematode specimens under a microscope, compares them with a database held on file and thus allows taxonomic identification. It was adapted to select automatically from different subsets of characters applied to cysts and juveniles. Four similarity statistics were incorporated in the program, and their utility and efficiency investigated (with P. B. Topham, B. Boag[1]).

The use of a data logger in the field or at a remote site for recording temperature and rainfall in a crop requires weekly or monthly access to the logger to recover the stored data, and normally entails returning it to the laboratory. To avoid this return trip, a data transfer program was written for the EPSON HX20 portable microcomputer to capture data from a data logger on magnetic tape for transfer to a BBC microcomputer for graphical analysis.

The HERBREX maintenance program is used to create the tables of weed susceptibility to herbicides incorporated in the HERBREX information file. An option was included to facilitate the production of similar tables for publication in the HEBREX Bulletins. Two Bulletins were published one dealing with herbicides and desiccants for potatoes and one for spring and winter barley.

(P. Smith)

Statistics

Relationships between black currant yields and weather parameters were examined. Data on yield and dates of flowering during 1960-1986 for the black currant cv. Baldwin were obtained from Brogdale EHS, Kent. The weather data, collected daily at Faversham during these years, consisted of air maximum and minimum temperatures, grass minimum temperatures, sunshine hours, rainfall and windspeed. Data on soil moisture deficits was also available.

The weather parameters for each year were observed through a 'window' of width ranging from 1 to 10 days, and offset from the date of the grape stage of flowering for that year by −21 to +40 days. The changing pattern in correlations between the weather parameters and yield were examined as a function of window width and offset.

All of the correlations lay in the range −0.5 to +0.5. Window width had little effect. For the air maximum, minimum and grass minimum temperatures, the correlations gradually increased with increasing offset from grape stage until about 30 days after grape stage. At this point the correlations dropped sharply to around — 0.4, after which they gradually rose towards positive values again. High negative correlations 30 days after grape stage were also evident for sunshine hours and rainfall, but there

[1]Zoology Department

were no other clear trends for these two variables. No clear relationships could be detected between soil moisture deficits and yield.

(J. W. McNicol[1], R. M. Brennan[2])

NIR

New features have been added to the near infra-red software. By converting a principal component regression/calibration model to its equivalent wavelength form and plotting the new coefficients against their corresponding wavelengths, an outline similar to the shape of the constituent spectrum is sometimes revealed. The display of such reconstructed spectra of constituents for which a constituent spectrum is not available, for example protein in barley, is of considerable interest. Using this wavelength model it is also possible to display an individual sample's contribution at each wavelength to the constituent — the dependent variable — of the regression model. This is achieved by plotting the reflectance energy times coefficient against the corresponding wavelength.

(J. W. McNicol[1], I. A. Cowe[3], D. C. Cuthbertson[3])

[1]SASS
[2]Soft Fruit Breeding Department
[3]Chemistry Department

VIROLOGY

B. D. HARRISON

During the past year Virology Department has considerably expanded the scope of its basic research, aided by the move of several staff into new laboratories in the recently constructed modular building. The aim is to take the great opportunities now offered by modern molecular biological and genetic engineering techniques both to investigate the ways in which biological characteristics of plant viruses are determined, and to alter viral activity. In work towards these objectives, a large part of the genome RNA of potato leafroll luteovirus has been sequenced; a start made in sequencing the genome of raspberry ringspot nepovirus; fusion proteins containing non-structural proteins of tobacco rattle tobravirus prepared; monoclonal antibodies to potato virus V found to detect a range of other potyviruses and to provide information on the conserved parts of potyvirus particle proteins; and, in ODA-funded work, evidence obtained that groundnut rosette disease, which causes serious crop losses in parts of Africa, is mainly caused by a satellite RNA which is dependent on groundnut rosette virus for its synthesis.

Other noteworthy findings include the discovery that different strains of tobacco rattle tobravirus are transmitted by different nematode species, that satellite-transformed plants are poor sources of cucumber mosaic virus for transmission by aphids, that some narcissus cultivars are resistant to the prevalent late season yellows virus, and that a previously undescribed virus of an unusual type occurs in cassava in the Ivory Coast.

Much of the Department's work has been done in collaboration with colleagues in other departments or organisations, and these links are proving invaluable aids to progress.

Nucleotide sequencing of potato leafroll luteovirus (PLRV) RNA [PU 15(k)]

In previous work, DNA complementary to PLRV RNA was cloned in plasmid pBR322. The sequence of much of this DNA has been determined by subcloning fragments made by restriction enzyme treatment into bacteriophage M13 and utilizing the dideoxy chain-termination method. Four large regions of contiguous sequence are known which comprise most of the PLRV RNA sequence, and the relation between the regions is being determined by further cloning experiments. The largest predicted translation product of one of these regions contains amino acid sequences thought to be typical of RNA polymerase molecules and which occur in polymerases

or putative polymerases of a number of plant and animal viruses. These sequences are no more similar to those in the putative polymerase of another luteovirus, barley yellow dwarf, than they are to those of other quite distinct viruses. However they are closely similar to those in the predicted translation product of beet western yellows luteovirus RNA and, more surprisingly, very similar to part of the amino acid sequence of the putative polymerase of southern bean mosaic virus, a virus which is unrelated to luteoviruses.

Selected DNA clones of known nucleotide sequence were supplied to the PLRV Link Group at the University of St Andrews for use in bacterial expression systems, with the aim of producing immunogens for antiserum production.

(M. A. Mayo, D. J. Robinson)

Cloned DNA copies of raspberry ringspot nepovirus (RRV) RNA [PU 15(g)]

As a first step towards determination of the nucleotide sequences of the genome RNA species of RRV, complementary DNA was prepared using an oligodeoxythymidylate primer and cloned in the plasmid vector pUC9. Almost 200 recombinant clones were isolated and characterized. Of these, 62 contained inserted cDNA of greater than 200 base pairs (bp) in length; 28 were more than 1 kbp in size and four were larger than 2 kbp. The largest cloned cDNA was 2.7 kbp long. Restriction enzyme mapping showed that the cloned cDNA represents a total of at least 6.2 kbp. Thus over half the genome of RRV has been cloned.

(J. A. Wardell[1], D. J. Robinson, M. A. Mayo)

Special electrophoretic properties of the particle protein of raspberry ringspot nepovirus (RRV) [PU 15(g)]

Previous work (*Ann. Rep. 1970,* 48) showed that the particle protein of RRV consists of one species with a mol. wt. of about 54K. In further experiments with RRV (strain S), in which discontinuous electrophoresis replaced the continuous system used earlier, a 44K component was found in addition to a 57K component. Purification of virus particles by centrifugation to equilibrium in caesium chloride or electrophoresis at pH 8.3 in acrylamide gel did not remove or diminish the amount of the 44K component and both it and the 57K component reacted strongly with antiserum to RRV particles in immunoblotting tests. Two dimensional electrophoresis showed that the 57K and 44K species co-migrated in a continuous system second gel and also that when both dimensions were discontinuous the 57K and 44K components were inter-converted reversibly. Protein that had been alkylated by treatment with iodoacetamide formed only a 57K component in either electrophoresis system which suggests that sulphydryl groups were involved in the formation of the 44K component

[1]Short-term Appointment

and thus that the mol. wt. of RRV particle protein is about 57K. When 2-mercaptoethanol was omitted from the buffer used to prepare samples prior to electrophoresis, the bands formed were diffuse and corresponded to mol. wt. of 57, 56, 55 and 44K. Presumably 2-mercaptoethanol breaks intra-molecular sulphydryl bonds and, except for those involved in forming the 44K component, these do not form again when the polypeptides migrate out of the sample buffer.

Similar artifacts caused by sulphydryl groups in proteins or revealed by the use of different electrophoresis systems have been found with other proteins including some from virus particles. However, no such artifact band was detected in protein from particles of tomato black ring nepovirus. Nevertheless the properties of RRV (strain S) protein emphasize the need for caution in interpreting the electrophoretic behaviour of virus coat proteins in general.

(O. Acosta[1], M. A. Mayo)

Replication of raspberry ringspot nepovirus (RRV) in inoculated protoplasts [PU 15(g)]

Previous work suggested that during the multiplication of RRV in protoplasts the differently sedimenting particles (T, M and B) of RRV accumulated at different rates dependent on the duration of the infection and on the plant species used as the source of the protoplasts. These suggestions were confirmed in further work. In protoplasts from *Nicotiana tabacum* cv. Xanthi, T particles accumulated more rapidly than B particles until about 50 h after inoculation. However, at 73 h after inoculation the numbers of T and B particles were similar, and those of each type were about eight times more abundant than M particles. In contrast, in protoplasts from *N. clevelandii,* B particles accumulated more rapidly than T particles until between 20 and 35 h after inoculation, when the accumulation of B particles almost ceased whereas that of T particles continued for at least another 40 h. In samples taken between 73 and 90 h after inoculation, T particles were three to four times more abundant than B particles and about 20 times more abundant than M particles. The accumulation of M particles did not cease so abruptly as that of B particles although, as in *N. tabacum* protoplasts, B particles were about seven times more abundant than M particles in the latest samples taken. The results show that virus multiplication in protoplasts of the two species of *Nicotiana* is controlled differently. This system therefore has potential for the study of virus-host interactions, when more biochemical detail of virus replication is known.

Previous work has shown that RRV RNA is translated *in vitro* as two large polypeptides with mol. wt. of 200 and 114K, which are thought to be cleaved into functional virus proteins in infected cells. As a first step towards establishing the pattern of events, the polypeptides synthesized in

[1]Research Student

RRV-infected protoplasts were compared with those synthesized in mock-inoculated protoplasts. Protoplasts from *N. tabacum* cv. Xanthi and from *N. clevelandii* were inoculated and then incubated in ^{35}S-labelled methionine for 6 h periods during the times when synthesis of virus particle protein seemed most rapid. Radioactive proteins were then analysed by a combination of isoelectric focussing and SDS-polyacrylamide gel electrophoresis. Infection induced many changes. In protoplasts from both plant species, prominent novel polypeptides of 105, 44 (two species) and 36K were found, together with less prominent novel polypeptides of 54 and 38K. In *N. clevelandii*, additional infection-specific polypeptides of 120, 96, 44, 38 and 30K were detected. Antiserum to RRV particles precipitated polypeptides of 57 and 44K. Several other polypeptides, which also occurred in mock-inoculated protoplasts, were most abundant in RRV-infected ones.

(O. Acosta[1], M. A. Mayo)

Stabilisation of particles of anthriscus yellows virus (AYV) [PU 15(f)]

AYV is a phloem-limited virus that is transmitted by the aphid *Cavariella aegopodii* in a semi-persistent manner and acts as a helper for the aphid transmission of parsnip yellow fleck virus (PYFV). Previous work (*Ann. Rep. 1986*, 161) showed that AYV particles have constituents resembling those of animal picornaviruses but that the particles disintegrate after a few days at 5°C, unless they are kept in 7 mM phosphate buffer, pH 8.0, containing 1 mM Ca^{2+}. When Ca^{2+}-stabilized preparations were injected into a rabbit, antibodies were obtained that coated AYV particles but reacted poorly in standard immunosorbent electron microscopy tests, in which the antigen samples were prepared in 7 mM phosphate buffer, pH 6.5. However, when the antigen preparations were prepared in 7 mM phosphate buffer at pH 8.0, containing 1 mM Ca^{2+}, many intact AYV particles were trapped. When the antigen samples were prepared in 70 mM phosphate buffer containing 1 μM phenylmethyl sulphonyl fluoride (PMSF), even more virus-like particles were trapped on the grids but these particles were penetrated by the electron stain. Thus the low yield and instability of AYV particles creates difficulties not only in obtaining an immune response but also in measuring its extent.

C. aegopodii that were allowed to feed through membranes on fresh Ca^{2+}-stabilized preparations of AYV particles failed to transmit the virus to test plants, although PYFV was transmitted from purified preparations by aphids that had previously fed on AYV-infected plants. The AYV preparations used in these experiments yielded a single nucleic acid species of the normal electrophoretic mobility. These observations suggest that transmission of AYV depends on a helper factor that was absent from the purified preparations.

(S. K. M. A. Hemida[1], A. F. Murant, G. H. Duncan)

[1]Research Student

Infection of protoplasts with parsnip yellow fleck virus (PYFV) [PU 15(g)]

Multiplication in synchronously inoculated protoplasts has given valuable insight into the molecular strategies of a number of plant viruses. As a preliminary to the study of the molecular biology of PYFV, protoplasts from leaves of *Nicotiana clevelandii* or *N. tabacum* were inoculated with purified particles of isolates P121 or A421 of PYFV. Although PYFV does not infect *N. tabacum* systemically, protoplasts from this plant were more readily infected than those from *N. clevelandii*. Isolate P121 infected more protoplasts (<80%) than did isolate A421.

(C. Greif[1], M. Mayo, A. F. Murant)

Production of tobacco rattle virus (TRV) fusion proteins [PU 15(g)]

The larger genome segment of TRV, RNA-1, contains three large open reading frames, of which the two at the 3′-end of the molecule comprise the codes for proteins of mol. wt. 29 and 16K, respectively. With the aim of preparing antisera specific for each of these proteins, DNA copies of these open reading frames were joined to portions of other genes so that fusion proteins for use as immunogens could be produced in bacterial expression systems. The *Escherichia coli* plasmid expression vector, pEX1, engineered to contain complete cDNA copies of the genes encoding the 29K or 16K proteins, was supplied by P. Guilford and D. Baulcombe.[2] In these constructions a small part of the phage λ *cro* gene fused to a truncated ß-galactosidase gene (*lacZ*) has been placed under the control of the strong λP_R promoter. In addition, a 12 base-pair oligonucleotide representing the four-amino-acid recognition sequence for human blood clotting factor X_a was inserted between the portion coding for the *lacZ* protein and the 29K-coding or 16K-coding portions of the fused gene. These vectors were used in bacteria harbouring a λ cI repressor which is active at 30°C but not at 42°C.

On culture at 42°C, large amounts of insoluble fusion proteins of the expected sizes were produced but these proteins were not cleaved by the blood clotting factor X_a, perhaps because its recognition sequence was not accessible. When the non-cleaved proteins were injected into rabbits, antibody was produced to ß-galactosidase but not apparently to the 29 or 16K proteins. Possibly the epitopes of these two proteins were not exposed but held internally in the 117K *cro lac* part of the fusion protein. In an attempt to overcome this problem the fusion proteins were cleaved with cyanogen bromide and the products used as booster injections for the immunized rabbits. Again no antibodies specific for the 29 or 16K proteins were detectable.

In an alternative approach, the 29 and 16K open reading frames in the pEX1 constructions were subcloned into a bacterial protein A expression

[1]Visiting Worker
[2]IPSR (Cambridge Laboratory)

vector with the aim of producing fusion proteins which could be purified as the result of the affinity of protein A for γ-globulin. Subclones producing the largest amounts and best quality fusion proteins were selected, and the proteins were produced in *E. coli* at 42°C and then purified by affinity chromatography on IgG-Sepharose. The purified product, although soluble and containing some degradation products, again could not be cleaved by factor X_a, so the uncleaved preparations were used to immunize mice. However, the antibodies produced did not react with the respective *cro lac* fusion proteins or with the products of *in vitro* translation of TRV-RNA.

A third approach is also being made, which uses the baculovirus expression vector pAcYM1 (Matsuura *et al., J. Gen. Virol. 67*, 1515, 1986). In this system the gene of interest is inserted into a pUC8-based vector to the 3' side of the promoter sequence of the polyhedrin gene of *Autographa californica* nuclear polyhedrosis virus. Plasmid DNA containing these constructions is then mixed with the virus, the mixture inoculated to insect cells and recombinant virus isolates which produce the protein of interest instead of viral polyhedrin are selected and used to produce large amounts of the new protein. Plasmid constructions containing the 29 or 16K genes were made and sent to IPSR (Cambridge Laboratory) for the production of recombinant virus isolates.

(R. Waugh[1])

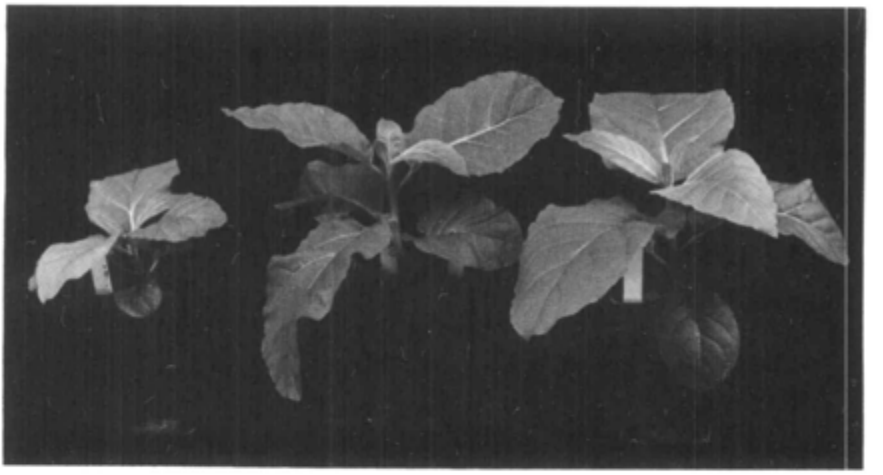
Genetic engineering of virus resistance [PU 15(h)]

Previous tests showed that tobacco plants transformed with DNA copies of cucumber mosaic virus (CMV) satellite RNA developed hardly any disease symptoms when they were manually inoculated with satellite-free CMV, which multiplied to only about 5% of the extent that it did in control plants. In these tests, manual inoculation with highly infective virus suspensions probably initiated infection in hundreds of cells in each inoculated leaf, thereby providing many chances of eliciting satellite RNA synthesis in the inoculated cells. However, natural transmission of CMV is by aphid vectors, which probably inoculate only one or a very few cells per plant. In further tests, the satellite-transformed plants were therefore inoculated, or used as virus sources, by vector aphids.

Satellite-transformed seedlings did not differ from control transformed seedlings in susceptibility to infection with satellite-free CMV inoculated by aphids, *Myzus persicae*. However, whereas the control plants that became infected all developed a mosaic and remained stunted, the satellite-transformed plants that were infected all remained mosaic-free, grew almost as well as uninfected plants (Fig. 1) and produced satellite RNA. When infected satellite-transformed and infected control plants were used as virus sources for aphids, the aphids from the control plants transmitted CMV to about eight times as many seedlings as those from

[1]Short-term Appointment

Figure 1



Effect of aphid-inoculated cucumber mosaic virus on control tobacco seedling (left) and satellite-transformed seedling (centre); uninoculated seedling (right).

satellite-transformed plants, reflecting the different concentrations of CMV in the two sources. Moreover, the few seedlings infected by aphids from the satellite-transformed plants developed only mild symptoms because the aphids had acquired and transmitted the satellite RNA along with the virus. This results from packaging of satellite RNA in many of the CMV-like particles produced in the satellite-transformed plants.

The satellite-transformed plants were found previously to develop few symptoms after infection with tomato aspermy virus (TAV), another cucumovirus. Further tests showed that symptom production is suppressed without any appreciable decrease occurring in TAV accumulation, and that the amount of satellite RNA produced in these plants is similar to the amount in CMV-infected ones. This indicates that some of the processes involved in symptom production can be separated from those involved in virus replication. When TAV was transmitted from the satellite-transformed plants by *M. persicae*, almost as many seedlings became infected as by TAV from control sources, but the satellite RNA was not transmitted to all the seedlings infected. The satellite-free seedlings developed much more severe symptoms than the satellite-containing ones. Evidently, this CMV satellite RNA is not well adapted to transmission by aphids from TAV-infected plants, perhaps because it is less readily packaged in TAV-like than in CMV-like particles.

(B. D. Harrison, E. A. Murant[1], D. C. Baulcombe[2])

[1]Short-term Appointment
[2]IPSR (Cambridge Laboratory)

Detection and field spread of narcissus late season yellows potyvirus (NLSYV) [PU 11(a)]

Previous tests (*Ann. Rep. 1986*, 170) indicated that NLSYV was best detected by ELISA in the distal part of narcissus leaves sampled after flowering, and that infection was detected more consistently in some cultivars than others. Further work confirmed and extended these results. In tests at four or five fortnightly intervals, NLSYV was detected most regularly in the cultivars Golden Harvest and Golden Ducat, and least regularly in the cultivars Corinthian, Lothario and Standard Value, with Counsellor and Irish Luck in an intermediate position. Infection was detected most readily from June until the leaves died off.

Based on the incidence of accumulated infection in commercial stocks, narcissus cultivars differ in susceptibility to NLSYV and can be placed in four groups: (1) no plants infected, (2) few plants infected, (3) most plants infected, and (4) all plants infected. To assess how these categories relate to field susceptibility ratings, 20 virus-tested plants each of cultivars representing these groups were planted within a NLSYV-infected field stock of a group 4 cultivar, Golden Harvest, and 10 plants of each cultivar were planted within an adjacent crop of a group 1 cultivar, Carlton. When indexed by ELISA after 1 year's exposure to infection within the infector stock of Golden Harvest, the incidence of NLSYV infection was: 11/20 in King Alfred and 7/20 in Golden Harvest (both group 4), 1/10 in Fortune (group 3), 2/10 in Corinthian (group 2) and 0/20 in both Carlton and Red Goblet (group 1). NLSYV was not detected in any of the plants grown within the adjacent commercial stock of the NLSYV-free Carlton. These results confirm that cultivars differ in resistance to infection with NLSYV in field conditions and indicate the importance of this type of assessment as a basis for selecting susceptible cultivars to use in epidemiological studies, and in tests to assess the effectiveness of methods of controlling virus spread.

(W. P. Mowat, S. M. S. Dawson)

Narcissus white streak disease [PU 11(a)]

The cause of narcissus white streak disease is not known although potyvirus-like particles have been found in affected plants. A proportion of plants of narcissus clone CAl-3, a clone known to be infected with narcissus late season yellows virus (NLSYV), developed white streak symptoms. However, immunoelectron microscopy tests showed that all particles (*c.* 400 particles were examined in each test) from a white streak-affected plant were coated similarly and throughout their length with antibodies from each of three antisera to NLSYV. There was no serological evidence for particles of more than one virus in the white streak diseased plant.

(W. P. Mowat, G. H. Duncan)

Spread of narcissus mosaic (NMV) and narcissus tip necrosis (NTNV) viruses [PU 11(a)]

NMV and NTNV are two commonly occurring viruses with unknown natural modes of spread. In further field trials, virus-tested plants, grown in mixtures with NTNV-infected and NMV-infected plants, were defoliated with a disc strimmer and indexed by ELISA in the following year. NTNV was detected in 3.8% of flailed plants and 2.5% of unflailed plants whereas NMV was detected in 2.5% of the flailed plants and in none of the unflailed ones. Further evidence for field spread of these viruses in unflailed plots was obtained from tests on virus-tested plants of the cultivars Carlton and Sempre Avanti grown in rows adjacent to rows of plants infected with NMV and NTNV. Of 80 Carlton plants exposed to infection for 2, 4 and 6 years, NTNV was detected in 0, 2 and 2 plants, and NMV in 0, 2 and 1 plants, respectively. Of 100 Sempre Avanti plants exposed to infection for 3 and 5 years, NTNV was detected in 6 and 1 plants, and NMV in 8 and 1 plants, respectively. In summary, flailing has thus far not been shown to be a main cause of spread of NMV and NTNV under commercial conditions of propagation, although field spread undoubtedly occurs. Neither virus has been found in Foundation Stocks, but vigilance will be needed to ensure that the viruses do not cause problems in Elite stocks (commercial phase of production).

(W. P. Mowat, S. M. S. Dawson)

Virus-tested narcissus clones [PU 11(b)]

As previously reported (*Ann. Rep. 1986*, 171) all clones of cv. Sempre Avanti selected for freedom from other viruses are infected with a newly discovered virus (code-named NQV). From two of these clones, CD3-4 and BD1-6, six plants free of NQV were identified by ELISA and propagated by twin-scaling.

The release to SNSA (F.B.) Ltd. of residual material, produced for the experimental phase of the virus-tested narcissus programme, was completed. In future, propagation of narcissus by SCRI for the industry will be done on a contractual basis. At the request of DAFS a reserve bank of virus-tested narcissus clones was established at SCRI.

(W. P. Mowat, S. M. S. Dawson)

Variants of nepoviruses infecting raspberry [PU 9(d)]

The occurrence of natural infection with arabis mosaic (AMV) and raspberry ringspot (RRV) nepoviruses in raspberry cv. Glen Prosen, which graft-inoculation tests had shown to be immune from infection with the Scottish type isolates of these viruses (*Ann. Rep.1986*, 172) has prompted an examination of variation among British field isolates of AMV and among Scottish field isolates of RRV. Seven AMV isolates had particles which were indistinguishable serologically and in electrophoretic behaviour in

agarose gels, but most of the isolates differed in herbaceous host range and symptomatology. A further isolate from grapevine in West Germany* was serologically indistinguishable from the others. In contrast, five British isolates of RRV were each distinguishable serologically by spur formation in double diffusion tests in gel. In immunoelectrophoresis, particles of an isolate from cv. Malling Exploit raspberry (RRV-MX) migrated rapidly as a single component, whereas those of the English (RRV-E) and Scottish (RRV-S) type isolates migrated more slowly, but also as a single component. Of two isolates from Tarvit, Fife, a site where Glen Prosen becomes infected, the first (RRV-Ta) had particles which migrated as two components, one with a mobility resembling that of RRV-MX and the other migrating slower than particles of RRV-E and RRV-S. The second isolate from Tarvit (RRV-TaD) behaved like the slower migrating component of RRV-Ta. Purified particles of each of the RRV isolates behaved similarly when sedimented in sucrose density gradients but those of RRV-MX were much the least stable. Protein preparations from highly purified particles of RRV-S and RRV-MX contained single polypeptides of estimated mol. wt. 55 K and 51 K respectively, whereas RRV-Ta protein contained two components with mol. wt. of 55 K and 50 K. Possibly the RRV-Ta culture is a mixture of two isolates, one of which resembles RRV-MX. These results indicate that considerable serological variation occurs among RRV isolates but little or none among AMV isolates. Whether this variation in RRV parallels that in other biological properties of importance in virus ecology and epidemiology is not clear.

(A. T. Jones, M. J. Mitchell)

Virus indexing of *Rubus* cultivars and selections [PU 9(e)]

During the year, four imported *Rubus* cultivars or breeders' selections and 66 selections from the *Rubus* breeding programmes at SCRI and IHR (East Malling) were indexed for virus infection. One raspberry selection and a blackberry cultivar, each imported from North America, contained virus(es) inducing tip necrosis in *Rubus occidentalis* but ELISA showed that neither source contained black raspberry necrosis (BRNV) or raspberry bushy dwarf viruses. Two raspberry selections from the SCRI breeding programme and five from the East Malling programme contained BRNV. Among 136 *Rubus* species, cultivars and selections maintained at SCRI, BRNV was detected by ELISA in two raspberry selections which had not induced obvious symptoms when graft-inoculated to *R. occidentalis*, suggesting that BRNV isolates may differ in the reactions they induce in this indicator species.

(M. J. Mitchell, A. T. Jones)

*Held under DAFS licence

Virus indexing of *Ribes* cultivars and selections [PU 9(e)]

Work was initiated during the year to introduce a scheme for the production and maintenance of virus-tested stocks of *Ribes* cultivars and selections from the SCRI breeding programme. Two gauze houses were erected for this purpose and indexing for known viruses should begin in 1988.

(A. T. Jones, M. J. Mitchell)

Restriction of potato leafroll luteovirus (PLRV) multiplication in *Solanum brevidens* [PU 13(j)]

In Peru, Jones (*Potato Research 22*, 153, 1979) reported that *Solanum brevidens* was resistant but not immune to PLRV and found that the virus reached only a low concentration in graft-inoculated plants. In tests at SCRI, 10 to 14 plants of each of three accessions of *S. brevidens* were graft-inoculated with a Scottish isolate of PLRV. About 8 weeks after inoculation, the PLRV concentration in foliage, measured by ELISA, was only about 2% of that in a susceptible *S. tuberosum* cultivar. Plants containing such a low concentration of PLRV are likely to be poor sources of virus for transmission by aphids, and *S. brevidens* is therefore a possible source of PLRV resistance genes.

(H. Barker)

Influence on potato leafroll luteovirus (PLRV) of co-infection with other viruses [PU 13(j)]

Previous work (*Ann. Rep. 1986*, 176) has shown, first, that PLRV is localised in phloem tissue of potato although in *Nicotiana clevelandii* it also occurs in a few parenchyma cells, and second, that when *N. clevelandii* plants are doubly infected with potato Y potyvirus (PVY) an increased number of parenchyma cells are infected with PLRV and its concentration is about eightfold greater. In further tests with a range of sap-transmissible viruses, the concentration of PLRV in *N. clevelandii* was increased six- to ninefold by co-infection with viruses in the tobravirus, potyvirus and potexvirus groups, and with carrot mottle virus. In contrast, PLRV concentration was essentially unaffected by co-infection with viruses in the bromovirus, cucumovirus or nepovirus groups, or with alfalfa mosaic or parsnip yellow fleck viruses. In tests with tobraviruses, the NM forms (particle-free isolates lacking RNA-2) of two strains were as effective as the particle-producing M forms for inducing an increase in PLRV concentration in doubly infected plants. Tests with a selection of these sap-transmissible viruses in co-infections with PLRV in *N. benthamiana* or with beet western yellows luteovirus in *N. clevelandii* revealed a pattern of behaviour resembling that of PLRV in *N. clevelandii*.

It is well established that PLRV is not normally transmitted either by mechanical inoculation of sap or through seed. Several unsuccessful attempts were made to transmit PLRV to either virus-free or PVY-infected *N. clevelandii* plants by manual inoculation with sap from plants containing a high concentration of virus particles, or with purified virus particles. Furthermore PLRV was not transmitted through seed of *N. clevelandii* plants infected with PLRV alone or with both PLRV and PVY. Nevertheless, co-infection of plants with sap-transmissible viruses may be a useful aid to further study of the mechanism of restriction of luteoviruses to phloem tissue.

(H. Barker)

Monoclonal antibodies (MAbs) to potato V potyvirus (PVV) [PU 13(k)]

Several of the panel of eight MAbs (SCR36 to 43) previously produced to PVV proved to be suitable for detecting the virus in potato leaf sap diluted to 1/1000 and did not react with potato Y potyvirus (PVY). In potato cultivars Home Guard, Famosa and Estima, PVV concentrations did not differ consistently between young, old and intermediate-aged leaves and the virus was detected reliably in sap diluted 1/20 from leaves of all ages.

Isolates of PVY reacted with one to three of the eight MAbs, and PVY^N strains shared an epitope with PVV that was lacking in PVY^O and PVY^C strains. In tests with 21 other aphid-transmitted potyviruses, MAb SCR 39 reacted with 14, SCR 40 with 7, SCR 43 with 3 and SCR 38 with 1. SCR 36, 37, 41 and 42 did not react with any of these viruses (See Table 1 for examples). Ryegrass mosaic virus reacted with SCR 39, emphasizing the affinity between this mite-transmitted virus and aphid-borne potyviruses. Two sweet potato viruses, suspected but not proved to have whitefly vectors, reacted with SCR 38 and SCR 39 respectively. The MAbs which distinguished PVV from all the other viruses coated PVV particles but did not react with denatured virus particle protein in immunoblots, whereas the cross-reacting MAbs did not coat the virus particles but reacted in immunoblots. The epitopes detected by the PVV-specific MAbs are therefore on the particle surface and conformation-sensitive, whereas those shared with other potyviruses are internal and sequence-specific. The reactivity of the sequence-specific epitopes was increased when the virus particles were disrupted by incubation at pH 9.5. Taking these results together with the known amino-acid sequences of the particle proteins of five other potyviruses, the picture which emerges is one in which a virus-specific N-terminal sequence is found on the external surface of the virus particles and the extensive highly conserved sequences are mostly internal. MAbs which react with these conserved sequences seem suitable for detection of selected heterologous potyviruses in addition to that of PVV.

(M-J Farmer[1], B. D. Harrison)

[1]Short-term Appointment

Table 1. Reactions of monoclonal antibodies to potato virus V with other potyviruses

Virus	Monoclonal antibody number							
	SCR 36	SCR 37	SCR 38	SCR 39	SCR 40	SCR 41	SCR 42	SCR 43
Alstromeria mosaic	0	0	0	+	0	0	0	+
Cocksfoot streak	0	0	0	+	0	0	0	0
Leek yellow stripe	0	0	0	0	+	0	0	0
Lettuce mosaic	0	0	0	+	0	0	0	0
Narcissus late season yellows	0	0	0	+	0	0	0	0
Potato Y^N	0	0	+	+	0	0	0	+
Potato Y^O	0	0	0	+	0	0	0	0
Potato V	+	+	+	+	+	+	+	+
Tobacco vein mottling	0	0	0	+	+	0	0	0
Turnip mosaic	0	0	0	+	+	0	0	0

A 'resistance-breaking' isolate of tobacco rattle tobravirus [PU 13(k)]

Although potato cv. Bintje is regarded as resistant to infection with tobacco rattle tobravirus (TRV) in the UK, there are sporadic reports of infections occurring in continental Europe. A TRV isolate from Bintje obtained from Sweden* was found to be NM-type (non-particle producing), as are most isolates from potato. A pseudo-recombinant isolate, made by adding RNA-2 from strain PRN (a Scottish isolate from potato) to the Bintje isolate, could not be distinguished from strain PRN itself by symptoms in herbaceous host plants. When the pseudo-recombinant isolate was manually inoculated to leaves of potato plants, it produced necrotic local lesions and occasional vein necrosis without systemic spread in both resistant and susceptible cultivars; but so did TRV strains PRN and SYM (an English isolate from spinach). Thus, no evidence was obtained that reactions of potato plants to manual inoculation are a useful indicator of resistance to TRV, and further investigation of resistance to, and resistance-breaking by, TRV in potato will probably require the development of methods for transmission of defined virus isolates to potato by vector nematodes.

(D. J. Robinson, F. J. Legorburu[1])

Isolates of tobacco rattle tobravirus (TRV) transmitted by naturally viruliferous nematodes [PU 13(k)]

Although it is well established that the natural vectors of TRV are trichodorid nematodes, there is little information on vector specificities of different isolates of TRV. To investigate this, methods were developed

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*Held under DAFS licence

(Zoology Report p. 130) to study the transmission of TRV by individual naturally viruliferous trichodorids from different sites. Eleven TRV isolates transmitted by individual *Paratrichodorus pachydermus* from a site at Barry, Tayside, were all of the PRN serotype, whereas eight isolates transmitted by *Trichodorus cylindricus* from the same site did not react with any of the antisera available. The two groups of isolates could also be distinguished by the symptoms they produced in White Burley tobacco: isolates transmitted by *P. pachydermus* caused necrotic lines and ringspots in all systemically infected leaves, whereas those transmitted by *T. cylindricus* induced symptoms only in the leaves immediately above those inoculated, or not at all. Twelve out of 14 isolates transmitted by *P. pachydermus* from a site at Kinshaldy, Fife were also of the PRN serotype. However, the other two isolates from this site were serologically similar to strain SYM, and also shared with it the uncommon ability to infect *Chenopodium amaranticolor* and *C. quinoa* systemically. These results show that distinct TRV isolates can co-exist at a field site, and that whereas in one instance their principal vectors are different species of trichodorids, in another instance they are transmitted by the same vector.

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

Virus isolates from mosaic-affected cassava in the Ivory Coast [PU 12(a)]

To assess the extent of variation among African cassava mosaic geminivirus (ACMV) isolates occuring within one country, tests with 20 monoclonal antibodies (MAbs) to the west Kenyan type culture of the virus were made on 70 infected cassava clones* collected over an area of 400 x 400 km and provided by C. Fauquet[3]. Sixty-five clones contained ACMV isolates which, like typical group A isolates, reacted with all 20 MAbs, four clones contained isolates which reacted with 17 MAbs and one isolate reacted with only 11 MAbs. This last isolate was transmitted to *Nicotiana benthamiana* but multiplied poorly and could not be maintained in this host by serial subculture. In antigenic specificity and behaviour in *N. benthamiana* it is typical of Group B isolates, which have not previously been recorded in West Africa. Further enquiry revealed, however, that its source cassava clone had been imported some years previously from Madagascar, where Group B isolates are known to occur (*Ann. Rep. 1986*, 179). The four other variants multiplied readily in *N. benthamiana*, and when so cultured showed the same pattern of reactivity with the MAbs as in cassava sap. These variants were not identical antigenically but they each lacked some of a small number of epitopes. Three of the four isolates came from places less than 60 km apart near the Ghana border, suggesting that ACMV variants may be particularly common in this small district. There was no correlation between antigenic specificity and symptom severity in either cassava or *N. benthamiana*.

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Typical Group A isolates, reacting with all 20 MAbs, were also identified in 10 clones of wild *Manihot glaziovii* or *M. glaziovii x M. esculenta*. In general, symptoms were confined to a few of the leaves on the plants and, even in these leaves, the concentration of ACMV was only about a tenth of that in symptom-bearing leaves of most cassava clones. Another typical Group A isolate was identified in a mosaic-affected plant of the euphorbiaceous species, *Jatropha multifida*.

(M. M. Aiton[1], B. D. Harrison)

Two other viruses were found incidentally in the cassava clones. One clone contained cassava common mosaic potexvirus, a rare unequivocal record of this virus outside the Americas. In addition, four clones, all collected from a region near the border with Guinea, contained a virus with bacilliform particles 18 nm wide and mostly 40 to 85 nm long. The virus was transmitted by inoculation of sap to *Chenopodium amaranticolor* and *C. quinoa*. Its particles did not react with antisera to alfalfa mosaic, ourmia melon, prune dwarf or prunus necrotic ringspot viruses and it seems not to have been described previously.

(M. M. Aiton[1], I. M. Roberts, B. D. Harrison)

Variation in Indian cassava mosaic geminivirus (ICMV) [PU 12(a)]

In previous work, three geminivirus isolates from India reacted with only three out of 20 monoclonal antibodies (MAbs) to the Group A type isolate of African cassava mosaic geminivirus (ACMV) from western Kenya. Tests on a further 17 isolates*, supplied by V. G. Malathi[2]and V. Muniyappa[3] from the Indian states of Karnataka, Kerala and Tamil Nadu, confirmed this general picture. Fourteen of these isolates reacted only with the same three MAbs, and the three others reacted with only two of the three MAbs. There was no evidence that two Kerala isolates obtained from cassava cultivars with strong resistance to infection (M4 and S1315) differed antigenically from isolates obtained from susceptible cultivars. All seven Kerala isolates tested were transmissible to *N. benthamiana* by inoculation with sap. Geminivirus isolates infecting single plants of *Jatropha glandulifera** and *J. curcas** reacted with two and one of the MAbs, respectively, and both lacked one epitope found in all the cassava isolates. There is therefore no evidence that *Jatropha* spp. are natural hosts of ICMV.

All five Kerala cassava isolates tested reacted strongly in nucleic acid hybridization tests with a probe for DNA-1 of the type isolate of ACMV, Group A, but only very weakly with a probe for the corresponding DNA-2.

(M. M. Aiton[1], P. F. McGrath[1], D. J. Robinson, I. M. Roberts, B. D. Harrison)

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Cassava Colombian symptomless virus (CCSV) [PU 12(a)]

Further serological tests showed that the virus isolate referred to previously as CM* shares few if any epitopes with cassava common mosaic (CCMV) or cassava X (CsXV) potexviruses and that it did not react in $F(ab')_2$-ELISA with antibodies, provided by R. Koenig[1], to nine other potexviruses, most of which originate from the Americas. In contrast, CCMV reacted with antibodies to narcissus mosaic virus, and CsXV reacted with antibodies to white clover mosaic and Argentine plantago viruses. The new cassava virus has filamentous particles measuring about 460 x 13 nm that contain a protein with estimated mol. wt. of about 26 K. The virus could be detected in naturally infected cassava by DAS-ELISA, and occurred in mixed infections with CsXV in symptomless plants of cv. CM-321. Although it occurred in some cassava plants with frogskin disease and some with caribbean mosaic, it does not seem to cause these diseases, either on its own or in combination with CsXV. Its host range includes *Chenopodium* spp. and *Nicotiana benthamiana* but it is confined to the inoculated leaves. The new virus has properties typical of potexviruses but is serologically unrelated to those tested. It seems to be undescribed previously and is given the name cassava Colombian symptomless virus.

(M. A. Aiton[2], B. D. Harrison)

Third country quarantine tests on cassava [PU 12(a)]

To facilitate the safe transfer of clonal cassava from the International Institute of Tropical Agriculture, Nigeria, to the Centro Internacional de Agricultura Tropical, Colombia, 17 clones were propagated from aseptic microplants and subcultures tested for 10 different cassava viruses by serological, infectivity and/or nucleic acid hybridization tests. No virus infection was detected and the clones were cleared for dispatch.

(M. M. Aiton[2], B. D. Harrison)

Viruses associated with groundnut rosette disease [PU 12(b)]

Groundnut (*Arachis hypogaea*) plants with rosette disease contain a manually transmissible virus, groundnut rosette virus (GRV)*, which depends on a luteovirus, groundnut rosette assistor virus (GRAV)*, for transmission by *Aphis craccivora**. Purified preparations of GRAV were made by treatment of groundnut leaf extracts with cellulase, followed by sucrose density gradient centrifugation. Yields of virus particles were about 0.5-1.0 mg/kg leaf material. The preparation contained isometric particles *c. 28* nm in diameter with a sedimentation coefficient ($s_{20,w}$) of 115*S*, a buoyant density in Cs_2SO_4 of 1.34 g/cm^3, and A_{260}/A_{280} of 1.86. The particles contained a single species of nucleic acid (presumably RNA), of

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*Held under DAFS licence

mol. wt. 2.09 x 10^6 and with no detectable polyadenylate sequence, and a single protein species, of mol. wt. 24 K. An antiserum produced in a rabbit had a titre of 1/256 in gel-diffusion tests and detected GRAV in leaf extracts by ELISA. GRAV particles reacted strongly in $F(ab')_2$-ELISA with antisera to bean leaf roll, beet western yellows, potato leafroll and tobacco necrotic dwarf luteoviruses, but not with antisera to carrot red leaf luteovirus.

(R. Rajeshwari[1], A. F. Murant)

No virus-like particles have been reported for GRV but infected plants yield infective ssRNA. Infected leaves also contain dsRNA with prominent electrophoretic species of 4.6 kbp (dsRNA-1) and 1.3 kbp (dsRNA-2), a very abundant species of 0.9 kbp (dsRNA-3), and numerous minor species of intermediate mobility. In studies with GRV(C), an isolate from groundnut plants with a chlorotic form of rosette, cDNA to dsRNA-1 reacted with dsRNA-1 and dsRNA-2 but not with dsRNA-3 or any of the minor dsRNA species; in contrast, cDNA to dsRNA-3 reacted with dsRNA-3 and several of the minor dsRNA species but not with dsRNA-1 or dsRNA-2. An isolate lacking dsRNA-3 (isolate G96) was derived from GRV(C) by passage through *Gomphrena globosa*. When dsRNA-3 eluted from agarose gels was melted and inoculated to *Nicotiana benthamiana* plants, it was not infective on its own but multiplied in plants that were also infected with G96. Similar results were obtained with sucrose density gradient fractions containing RNA molecules of the size expected for ssRNA-3. These results show that dsRNA-3 represents a satellite RNA. Addition of dsRNA-3 to the G96 culture resulted in a slight amelioration of symptoms in *N. benthamiana* and *N. clevelandii*. In contrast, only cultures containing RNA3 induced rosette symptoms in groundnut, though the symptoms were intensified by further addition of GRAV. The results show that the satellite RNA is largely responsible for rosette symptoms in groundnut.

(A. F. Murant, R. Rajeshwari[1], D. J. Robinson, J. H. Raschké)

In previous studies, done in collaboration with K. R. Bock[2], several resistant groundnut lines exposed in the field in Malawi to aphids carrying the groundnut rosette disease virus complex remained symptomless but became infected with GRAV, though not with GRV. In further collaborative experiments, scions of resistant lines were grafted in Malawi onto rosette-diseased susceptible groundnut stocks. Some of the plants showed rosette symptoms after several months and samples sent to SCRI* were found to be infected with both GRAV and GRV; dsRNA-3 was associated with all the GRV isolates. Plants that remained symptomless were infected only with GRAV. The results indicate that the resistant lines can become infected with GRV when exposed to strong inoculum pressure.

(A. F. Murant)

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A previously undescribed disease of groundnut, characterized by necrotic streaks on the leaves accompanied by slight stunting, was first recognized in Malawi by K. R. Bock[1]. In collaborative work, up to 30% of the plants in some fields visited in 1987, especially in the hotter regions in the floor of the Rift Valley, were found to be affected. The disease was named groundnut streak necrosis (GSND). Diseased plants tended to occur predominantly singly or in pairs and there was no evidence of spread from primary foci within the crop. The disease agent was transmitted from diseased to healthy groundnut plants by grafting but not by *Aphis craccivora*. A virus* was transmitted by mechanical inoculation from affected plants to *N. benthamiana* and *N. clevelandii*, and was found to have properties similar to those of GRV (sensitivity of infectivity to organic solvents and to freezing; no virus-like particles detectable in leaf extracts). Preparation of dsRNA from infected *N. benthamiana* contained electrophoretic components similar to, but of slightly different mobilities from, those of GRV, with prominent species of mol. wt. *c.* 3.5×10^6 (dsRNA1) and 1.0×10^6 (dsRNA-2), and in some isolates but not all, a very prominent species of mol. wt. *c.* 0.5×10^6 (dsRNA-3), together with numerous minor components of intermediate size. What appears to be the same virus, with a similar dsRNA composition, was transmitted by *A. gossypii* from wild plants of *Tridax procumbens* (Compositae) to groundnut, in which it induced typical GSND symptoms. The virus from *T. procumbens* was also transmitted by *A. gossypii* to sunflower, in which it induced symptoms typical of sunflower yellow blotch disease (SYBD), previously described from Kenya. However, *A. gossypii* could not acquire this virus from groundnut or sunflower. The results suggest that GSND and SYBD are caused by the same agent, and that this agent resembles GRV in some of its properties, including perhaps dependence on a helper virus for transmission by aphids, and the possession of an associated satellite RNA. However, the different symptoms it induces in groundnut and the different mobilities of its dsRNA species indicate that this virus is not the same as GRV.

(A. F. Murant, R. Rajeshwari[2], J. H. Raschke, I. M. Roberts)

Preparation of cryo-trimmed specimens for scanning electron microscopy [PU 16(b)]

A 'cryo-trimming' technique was devised to reveal internal structures of specimens examined by scanning electron microscopy. Thick sections, which could be used for light microscopy, were cut from frozen specimens using a cryotome (Bright Instrumentation Co. Ltd) to leave a polished face on the specimen. Unlike freeze-fracturing, this trimming could be done accurately to a desired depth in the tissue. The polished specimens were examined either in a frozen-hydrated state using an Emscope SP2000

[1]ICRISAT, Malawi sub station
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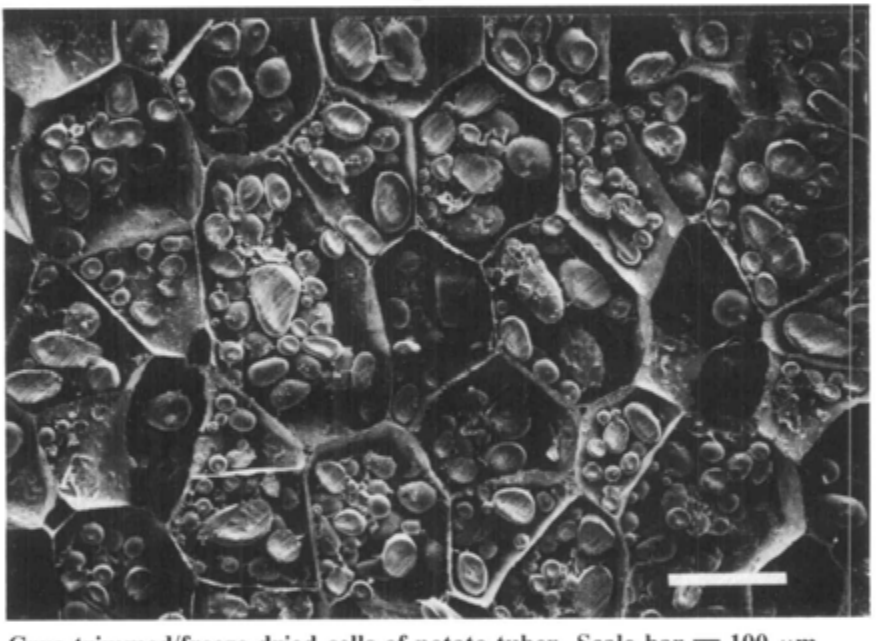
cryo-sputter system or, more simply, freeze-dried followed by gold or carbon coating. In both kinds of specimen, artifacts caused by ice crystal formation made interpretation difficult. However, in freeze-dried samples these fragile artifacts were removed by brief exposure to moist air to reveal more useful internal detail. No chemical fixation or dehydration was used, so that X-ray elemental analysis can be done directly on the specimens. Various materials wer examined using cryo-trimming viz. potato tuber (Fig. 2), raspberry drupelets, barley grains, nematodes, nematode cysts and eggs, and parasitic fungi.

(G. H. Duncan)

Figure 2



Cryo-trimmed/freeze-dried cells of potato tuber. Scale bar ≡ 100 μm

Detection of tobacco rattle tobravirus (TRV) by spot hybridization [PU16 (c)]
Further testing of naturally-infected, field-grown narcissus plants from various sites in eastern Scotland confirmed that spot hybridization with an RNA-1 specific probe detected all isolates of TRV encountered, regardless of serotype. In contrast, ELISA detected only isolates of one serotype with each antiserum, and many isolates did not react with any of the antisera available.

The value of spot hybridization was also demonstrated by its ability to confirm the identity of a virus, isolated by F. Bem[1] from a serious outbreak of disease in tobacco in northern Greece, that was believed to be TRV but which did not react with any of the TRV antisera tested.

[1]Benaki Institute, Athens

Application of the spot hybridization test to potato tuber tissue has previously given unreliable results, because of difficulties in making suitable extracts. Now however, a method has been devised in which small pieces of tuber flesh are disrupted with a mechanical drill in a small volume of buffer containing 8M guanidine hydrochloride. Much of the starch is removed by centrifugation of the slurry, and after extraction of the supernatant fluid with phenol + chloroform and precipitation with acetic acid + ethanol, remaining carbohydrate is washed out of the precipitate with 3*M* sodium acetate. The resulting preparation has a spectrum typical of nucleic acid. In spot hybridization tests, extracts made in this way from areas of tubers showing spraing symptoms reacted with the TRV RNA-1 probe, whereas extracts from unaffected parts of the same tubers did not. Thus, this extraction method should allow reliable diagnosis of TRV in spraing-affected potato tubers, as well as investigation of the distribution of virus RNA in them.

(D. J. Robinson, F. J. Legorburu[1])

ELISA using an avidin-biotinylated-enzyme complex [PU 16(c)]

Pre-formed avidin-biotinylated-enzyme complex ('ABC'), used in conjunction with biotinylated protein A to detect antigen-bound antibody, was tested as a means of enhancing the sensitivity of ELISA. This system was compared with a standard form of $F(ab')_2$-ELISA using a protein A-enzyme conjugate. Both systems were equally sensitive for detecting narcissus late season yellows and tulip chlorotic blotch potyviruses in leaf extracts with alkaline phosphatase as the enzyme. With horseradish peroxidase as enzyme, the 'ABC' system was less sensitive than the standard ELISA procedure. Thus the 'ABC' system did not have any obvious advantage in these tests.

(W. P. Mowat, S. M. S. Dawson)

[1]Visiting Worker

SCOTTISH AGRICULTURAL STATISTICS SERVICE

R. A. KEMPTON

A unified statistical service for the Scottish Agricultural Research Institutes and Colleges was set up by DAFS on 1st April 1987. The Service, which is administered by the Scottish Crop Research Institute, is centred in the King's Buildings of the University of Edinburgh with units in Aberdeen, Ayr and Dundee. It comprises some 20 consultant statisticians with a small central group of computer specialists and support staff.

SASS was created to make more efficient use of the statistical expertise existing in the former AFRC Unit of Statistics and among statisticians working in institutes. Contacts between scientists and statisticians are being strengthened by locating more statistical consultants at institutes and running regular consultancy clinics at sites where there is no resident statistician. This has led to an increase in statistical collaboration, particularly in new scientific areas of application where the relevance of statistical concepts is sometimes not recognized. As well as local provision of statistical advice, coordination of statistical services allows some statisticians to be assigned responsibility for supporting certain broad areas of application across all DAFS institutes. For example, special emphasis is being placed on coordinating and initiating work in chemometrics, environmental studies, food technology and image processing. A statistician has also been assigned to provide overall support for DAFS modelling work, to bridge the gap between the statistical and mechanistic approaches to biological modelling.

A coordinated programme of statistical training is also under way, aimed at increasing the statistical awareness and skills of scientific staff as well as providing instruction in the use of statistical packages. This will assist scientists who are undertaking routine analysis of their data and help them identify when statistical advice should be sought.

The SASS unit at SCRI is being set up under the leadership of J. W. McNicol and will comprise three consultant statisticians. The unit has special interest in the design and analysis of crop experiments, biological modelling and chemometrics. The number of projects undertaken this year has been restricted as two posts are still to be filled, but scientists should soon experience the benefits of having access to a much wider pool of statistical and mathematical expertise within SASS.

ESTATE DIVISION

W. I. A. JACK

The policy of improving the Division's services to scientific departments enabled an increase in field trials of 7.6% and glasshouse plant production and maintenance of 13.8% to be accommodated in 1987, which showed the effectiveness of the changes to the organisational arrangements introduced last year (*Ann. Rep. 1986,* 186). Further measures were introduced leading to improvements in record keeping, organisation and the facilities provided by the Estate Division: the recording of inputs made by Estate staff to field trials are now logged on a permanent computerised data base for easy access by scientific staff, and the organisation of the services for glasshouse, field trial and farm requirements at Pentlandfield, The Murrays and Blythbank farms are now co-ordinated.

The standard modular system of land use for field trials was implemented to cover all arable crops leading to improved access and to enhancement of the appearance of plot layout; and the underground irrigation ring-main from the bore hole at Mylnefield and Gourdie farms was completed by the end of the year. An extensive soil survey of all the Institute land at Dundee, which was completed by the staff from the MLURI now provides a descriptive soil profile map.

Unlike many industrialists, farmers have to operate in the unreliable natural environment and have to adjust their decisions according to the prevailing circumstances, but with no guarantee of ultimate success.

As the meteorological records show, the weather in 1987 was never ideal for most farming operations with a cold and late spring and the critical growing months of April to July sunless and at times cool; however the events of the harvest dulled this memory. Despite the prevailing weather conditions the portents for arable and soft fruit crops looked outstandingly good; however what was experienced was a disasterous and prolonged harvest for most crops, due to frequent periods of rain, numerous machinery breakdowns with seemingly endless delays for spare parts, and finally difficulties in selling poor quality produce in overloaded markets.

Farm Crops

Farm crops included 68.5 ha spring barley, 19 ha grass, 17.5 ha winter wheat, 5.5 ha field bean, 1 ha potato, 1 ha turnip and 15 ha fallow; this is an increase of 6.7 ha from 1986.

Sowing of barley cultivars Camargue, Esk and Tweed which was started on 19 March into slow drying and cold seedbed conditions, was frequently interrupted by rain and was finally completed on 16 April; germination was slow but establishment of a plant stand was satisfactory. Outbreaks of mildew (*Erysiphe graminis*) occurred in Tweed which required fungicide sprays. Combining started on 25 August, but progress was slow as a result of delayed ripening and took 23 days to complete. The average yield was down 0.7 t/ha on the previous years with the individual cultivar yields of 4.9 t/ha Camargue, 6.5 t/ha Esk and 3.9 t/ha Tweed; due to a high nitrogen and 'screening' content only 28.6% of the crop met malting market standards.

Wheat cv. Galahad which was sown in the autumn of 1986 over-wintered well and plant populations were satisfactory in the spring. However the potential yield was not realised due to a combination of the cool and sunless months of April to July together with atrocious harvesting conditions. Harvesting started on 8 September, but with ground conditions so bad in one field that machinery could not move we had to resort to scything and carting to the combine to complete the harvest. The yield of 6.2 t/ha was up 1.1 t/ha on the previous year, with 20% of the crop going for milling.

The growth of grass was slow due to the prevailing weather conditions and only a light crop of hay from 3.6 ha was made. Cutting started on 25 June and baling was completed on 6 July, the yield of 6.1 t/ha was up 0.7 t/ha on the previous year. Reservoir and Low Pilmore fields were grown for green manuring in preparation for cereal trials in 1988.

Field bean cultivars Herz Freya and Alfred were sown on 17 March into the best of the spring seedbed conditions. However plant populations were low and subsequent weather conditions reduced pod numbers leading to a reduced yield. The crop was harvested from 26 October onwards and was almost completed by the turn of the year. The yield of 3.1 t/ha was down 1 t/ha from the previous year.

Potato cultivars Maris Bard and Maris Piper grew well and sprays were applied fortnightly against pest and diseases. Lifting started on 6 July with Maris Bard and, on 6 October with Maris Piper. The quality of the harvested crop was excellent although the full potential of the main ware crop was not realised due to the failure of the crop to bulk-up; 15% of the crop was found to be below the minimum riddle size. Maris Bard yielded 45 t/ha and Maris Piper 35.5 t/ha, compared with 23.6 and 51.8 t/ha respectively in 1986.

The protracted harvest and wet land conditions, caused a hindrance to the routine autumn and winter work programme of stubble cleaning, straw incorporation, liming, sub-soiling and ploughing, and as a consequence a contractor was hired to plough a proportion of the land requirement for winter cereals.

Winter barley cv. Magie was sown in fairly good seedbed conditions between 2 and 14 October and winter wheat cv. Galahad was sown into

difficult seedbed conditions between 4 and 6 November; germination and the plant stand was reasonable for the winter barley but very poor for the winter wheat.

Italian ryegrass was sown on 2 October and entered the winter in fine condition.

Estate work was confined to Gourdie farm where a further 900 m of security and vermin proof fencing was erected on the east and south boundaries of Reservoir field and the boundary fence round the Gourdie farm buildings.

New farm equipment acquired during the year included an electric sack stitcher, a tractor mounted post driver and additional two-way radio Pocketfones, a secondhand hayrake; a Dutch harrow combination was moved to Mylnefield from The Murrays farm.

(R. W. Reid)

Field Experiments

There were 310 field experiments and off-station trials. The crops grown included 10 ha raspberry, 6.5 ha black currant, 2 ha strawberry, 1.5 ha black- and hybridberry, 21.25 ha cereal, 9 ha brassica, 4.75 ha potato, 1.75 ha field bean, with a miscellany of minor crops occupying a further 5.75 ha.

In comparison with 1986, the most noticeable difference is in the cereal area. The areas occupied by spring barley and winter barley trials increased by 20 and 60% respectively.

A standardised modular system of layout was implemented for potato trials, putting them on the same footing as brassica, cereal and field bean trials, and this proved to be a great success.

The installation of underground mains to provide water for irrigation has now been completed for Gourdie and Mylnefield farms. The weather conditions during 1987, however, denied the opportunity of testing the system to its full extent. Limited usage at Mylnefield showed it to be a very easy to operate and useful facility.

Scientists from the MLURI completed a systematic soil survey of all the Gourdie and Mylnefield land areas. The data collected provides detailed and up-to-date information on all aspects of soil structure, series, profile, and composition relevant to the cropping and trialling undertaken at SCRI, Invergowrie. The data aids the siting of a trial on a uniform soil type, selection of the most appropriate location for an experiment, and the choice of method for most effective preparation of ground.

The recording of inputs made by this Division to field experiments and trials is a massive undertaking, and it is no longer feasible to maintain, duplicate, or search these data manually. The data comprises records of fertilizer, pest-, disease-, weed-control, and other inputs, made in accord with standard management practices or in response to specific instructions.

The information is now, therefore, logged once by hand and then transferred to a permanent, structured, data base file via EMAS-A to ERCC. Sponsors can readily 'view' this file to check what inputs have been made to any trial and obtain a print-out of the information if required.

(G. Wood)

Soft Fruit

A reasonably mild winter enabled the fruit work to be completed on schedule. However, government legislation banning the use of dinoseb meant that in the spring a lot of man-hours were occupied in hand-cutting raspberry spawn which otherwise would have been chemically destroyed.

Fruit picking of strawberries commenced on 3 July. The early fruit was very promising but overall the crop finished approximately 25% below its potential. Raspberry picking started on 13 July. This crop was exceptional for freezing quality fruit. The first black currant picking was on 8 July. On 28 July the Tayberry, blueberry and blackberry picking started, with the latter continuing to crop until early November.

Problems were encountered in all fruit plots this year due to the ineffectiveness of the herbicide simazine in controlling groundsel.

It was noted that the damage caused by mechanical harvesting of raspberry experiments resulted in the necessity of replacing a substantial number (33%) of posts in some plots.

The transfer of black currant selections to new fruiting locations was completed by the end of November instead of being delayed until April. This was of significant benefit because apparently the plants did not experience a check, and the original site was cleared earlier and prepared for the rotational break-crop in a timely manner.

The spacing between raspberry rows (and consequently the area occupied by trials) has increased from 1.8 to 2 m over the last decade, and in 1987 this was amended to a 2.25 m standard. These changes have been necessitated principally by increases in tractor size. Also now adopted as standard practice is the pre-planting soil sterilisation of areas allotted to soft fruit breeding and the National Fruit Trial, a treatment which apparently promotes more uniform and rapid establishment of the plants.

(D. S. Petrie)

Brassica

The standard modular layout of trials is working well both for the sponsors and for Estate staff. The two factors of particular concern this year were the wet conditions that prevailed, and 'problem' weeds.

In general, seedbeds this year were wet, and on several occasions so wet that drilling was delayed. Drilling started with kale on 30 April followed by swede on 6 May and forage rape on 17 June. Torrential downpours in June

caused a lot of surface 'run-off' due to the slope of the brassica field at Gourdie farm. Sticky, wet ground also severely hindered machinery access during harvesting operations both on and off the Institute. Harvesting started with turnip on 19 October followed by forage rape on 26 October, kale on 10 November, and swede on 24 November. Harvesting operations continued well into December under difficult conditions.

Couch grass was a serious problem weed this year in Gowrie East field. Many man-hours were occupied in hand-weeding.

(A. Pirie)

Cereal and field bean

Sowing conditions for spring barley trials in High Land field were reasonable at first, but with c. 50% completed, drilling operations were rained off for almost a fortnight. This had a knock-on effect when it came to weed control. The crop was at widely differing stages of growth, and flushes of weed germination were spread over a considerable period of time. Effective weed control was, therefore, very hard to achieve. Indeed, in some areas the weed infestation was so bad that harvesting was seriously affected and reliable results were unobtainable from trials in such sites. The winter barley trials overwintered well and were not so seriously affected by the adverse conditions. Harvesting was straightforward and took place in good weather.

Symptoms of apparent manganese deficiency were again widespread among the spring cereal trials and caused great concern. Foliar applications of the trace element did not alleviate the symptom expression. Top dressings of additional nitrogen had a cosmetic effect but resulted in very soft straw which did not help harvesting. Soil analysis, however, revealed Mn levels to be perfectly satisfactory and that its availability was not restricted by high pH. Spring barley which had been combine-drilled into normally prepared seedbeds surrounding the trials did not manifest any of the apparent deficiency symptoms, suggesting that firm seedbeds and placement of the fertilizer with the seed appear to be critical factors for nutritionally healthy cereals on the relatively light land here.

Field bean trials were sown very late during April instead of at the preferred time of February. The ban on the use of dinoseb effectively removed the only post-emergence herbicide available, which together with the excessively wet conditions, resulted in many of the trials being badly weed infested. Although most of the beans were drilled for seed production, sponsors were reticent to desiccate the crop which resulted in the straw not ripening due to the wet weather, and combining was a nightmare which continued throughout November. A large percentage of the seed was lost on the ground.

The drilling of winter cereal trials began during September and progressed until disrupted by wet weather during October. The crop has established well.

(D. G. Pugh)

Potato

The wet weather which so badly affected other annual crops did not disrupt potato work, and staff experienced the unexpected bonus of being relieved of the arduous task of laying out extensive networks of irrigation piping.

Planting was completed in April. Preventive blight sprays commenced in June and continued at regular intervals into September. Lifting operations were notable this year for the increase in demand for the hand-digging of plots. This resulted in some large areas of trials still unlifted by November, which put at risk the clearance of fields and timely cultivations for the rotational break.

Adoption of the modular layout is an unqualified improvement over previous years. All aspects of planting, maintenance and harvest are made easier by this system.

(C. C. Carrie)

Glasshouses

In 1987 the production and maintenance of plants increased by 23,137 to 189,744 units, largely due to substantial increases from the Cereal Breeding, Estate, Mycology and Bacteriology, Physiology and Crop Production, Tissue Culture, and Zoology Departments. The department totals were 53,873 Virology, 42,418 Mycology and Bacteriology, 20,043 Estate, 17,084 Brassica Breeding, 16,532 Soft Fruit Breeding, 12,318 Zoology, 12,202 Cereal Breeding, 4,614 Physiology and Crop Production, 300 Tissue Culture. In addition 10,360 units were produced for ODA funded work.

Other projects included the propagation of 500 *Rubus* Nuclear stock 'mother' plants from 131 cultivars to provide a source of root material for pot plant production in 1988, and 56 *Ribes* nuclear stock 'mother' plants from 26 cultivars to provide a source of material for propagation. Root from nine raspberry cultivars was dispatched to NSDO to produce 12,800 pot plants for first stage nursery production.

During the year glasshouse staff have rebuilt many glasshouses, poly tunnels and Tygan structures which have had to be resited due to building developments. Also, sand beds were installed to facilitate clubroot work for the Mycology and Bacteriology department and four mini-mist benches were constructed within the propagation glasshouse which allows small batches of plants to be isolated from any pest and disease problems associated with routine large scale propagation that is being done.

(A. Lindsay, R. Ogg, J. Small)

The Murrays Farm

Timeliness of field work in 1987 was difficult with the constantly wet weather. Work tended to be rushed and only potato planting found a sufficiently large weather window to proceed smoothly.

Cottage and Longrigg fields were cropped for hay. Early in the season some excellent fodder was baled but in the main quality was variable. Potential yields were very high but insufficient sun resulted in considerable deterioration prior to baling. Outside storage was a particular problem with the torrential rains and wind damaging protective polythene sheeting.

Spring corn was drilled through late March to mid-April. The crops grew well following a slow and later than average emergence. Mildew was again the only foliar disease requiring fungicide application. Some *Rhyncosporium* was noted in damp headlands especially in areas of high fertility. The grain crop was sold for malting, and the baling was done by the straw contractor. Nitrogen varied between 1.2 and 1.6% depending on field and cultivar. Yields were moderately high, with cv. Blenheim averaging 6.8 t/ha over 36 ha.

The winter wheat came through the winter well and responded excellently to the spring application of nitrogen. Moderate levels of yellow rust appeared in the wheats, primarily in cv. Longbow but spreading quickly to cv. Norman and to a lesser extent cv. Brimstone. The wheat averaged a disappointing 7.9 t/ha, the crop was sold for feed and distilling. It was not possible to bale the straw, which was eventually chopped and ploughed in.

Combining of both winter and spring corn was long and tedious, the combine rarely working for longer than 3 hours at a session. By mid-September the wheat crop was becoming badly lodged and slow to dry prior to combining. Later in the month conditions improved dramatically.

Potato plots were grown in Potato Shed West field, with early trial material in the northern portion. Growth was vigorous, with surprisingly a minimal number of insecticide applications being required, and only one spray for blight control was applied. Desiccant spray was applied prior to harvest which commenced in mid-July and was completed in October. No commercial crops of potatoes were grown this season.

Cereal and brassica cultivar assessment trials for the Cereal and Brassica Breeding Departments were sited in Crow and Potato Shed fields, and large demonstration plots in Crow field were used at an NSDO Cereal Open Day.

(I. M. Chapman)

INFORMATION SERVICES

R. J. A. EXLEY

Subject to DAFS approval, the recommendations of a visiting AFRC Management Audit Unit team form the basis for adjustments by the Director to the staff grades and staffing levels within a support division. Information Services was inspected in 1982 following the amalgamation in 1981 of the former SHRI and SPBS, but the recommendation was made that certain aspects should be reviewed when physical integration was completed, perhaps in two years' time. Integration was still incomplete in 1987, but the Director decided to have the further inspection and this was held in June.

Information Services was originally staffed to serve a markedly different organisation from that which now exists. Since the last inspection, SCRI's remit and support-staff : scientist (Scientific Officer and higher grades) ratio have changed beyond recognition. Also, the Institute's remit has broadened to include three major groups of crops of national importance (cereals, potato, brassicas), and 'intensified' in some areas because of the Institute's sole or predominant UK role including black currant, forage brassica and raspberry breeding, and potato physiology. SCRI is now the largest SARI and arguably it has the widest range of crop type and scientific discipline in the research programme of any ARFS institute, which has increased the responsibility and workload, and widened the expertise that is required.

The total Information Services staff : scientist ratio in 1981 (pre-merger) was 1:9.2, which was considered satisfactory and the staff were fully employed. In 1985 the ratio was 1:11.4 and in June 1987 1:16.6. The demands have increased across the board; internally for library and visual aids services, and externally by an increased exposure of SCRI's work through publications and promotional activities of all kinds. Although benefits of scale can be expected from capital resources and overheads, staffing level is the pre-eminent constraint on the output of services which are 'customer driven' and therefore routinely require personal dialogue and a quality product.

The outcome of the inspection is still awaited.

LIBRARY

During the year books and journals on tissue culture and chemistry were moved to Mylnefield from Pentlandfield, and the computerised literature search service was also transferred. The provision of all library services is now organised from Mylnefield, but a weekly visit was made to Pentlandfield by library staff throughout the year.

By the end of the year, 93 people were receiving the weekly journals list, 1095 items had been borrowed from stock at Mylnefield, and 1952 items obtained by inter-library loan. Also, there had been 81 literature searches and three automated current awareness searches for research staff. These figures show a 25% expansion in the use of library services compared with 1986, which is accounted for by the arrival of new staff and staff transferred from SCRI Pentlandfield and the former MISR. Another consequence of this expansion was the need for a wider range of journals, and the ending of the internal journals circulation system.

The Librarian attended this year's meetings of the Scottish Agricultural Librarians' Group in May at the Countryside Commission for Scotland at Battleby, Perth, and in October at the Royal Botanic Gardens, Edinburgh.

(U. M. McKean)

VISUAL AIDS

Production figures for the year again increased overall, especially in the number of graphics produced which at 2534 is a rise of 156%

	PHOTOGRAPHY					GRAPHICS	
	Jobs	Colour	Monochrome	Diazo	EM/Prints	Jobs	Graphics
1986	2291	8746	11646	967	2137	242	986
1987	2284	9656	11703	979	2184	298	2534

As the table shows the number of jobs undertaken can be misleading. For instance, one job involved the production of 42 colour prints, 48 monochrome negatives, 36 line negatives, 374 monochrome prints and 158 line prints; the time taken to complete this particular task was 65 man hours.

Among the more unusual investigations involving photography were studies of the colonisation and damage to pot grown raspberry plants by the adult clay coloured weevil (*Otiorhynchus singularis*) using time-lapse colour cine filming. The nocturnal nature of the subject required a lighting exposure using a studio flash at 2 min intervals for the 5½ day duration of the experiment.

The feasibility was assessed under field conditions of using video images of young rape plants to measure their leaf area. The video recording is replayed and the area is calculated from measurements of the monitor image using a two-way mirror, digitising tablet and micro computer. This technique should be quicker and cheaper than traditional methods.

Many displays of the Institute's work were produced throughout the year, and at some venues were mounted alongside those of large private companies with larger promotional budgets. To maximise the standards of presentation from our available resources custom-made lettering, airbrush work, specilised colour printing and three-dimensional graphic techniques were employed. These techniques are very labour intensive and if such prestigious presentations are to be continued, the standard of other more routine work is likely to be penalised.

(T. G. Geoghegan)

SCOTTISH SOCIETY FOR CROP RESEARCH

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Report by the Committee of Management

The Committee of Management met on three occasions (1 April, 20 July, 18 November) during 1987 for the transaction of Society business. There were also meetings of the Crop Sub-Committees at various times throughout the year.

During the year a number of meetings for members of the Society and guests were arranged. These included:–

(i) Cereals Meeting held in the Invercarse Hotel, Dundee on 27 January,
(ii) Soft Fruit Meeting held in the University of Dundee on 4 February,
(iii) Fruit Walk held at Mylnefield on 18 July,
(iv) Cereal Breeding Demonstration at Gourdie Farm, Dundee on 20 July

During the year the Committee authorised the payment of grants for travel as listed below:–

(i) From the General Fund:

£250 to D. M. Kennedy (SCRI Mycology & Bacteriology Department) attending Washington, British Columbia and New York State in April.

£300 to D. K. L. MacKerron (SCRI Physiology & Crop Production Department) attending Agrometeorology of the Potato Crop Symposium, Wageningen, The Netherlands in April.

£250 to J. S. Swanston (SCRI Cereal Breeding Department) attending research and plant breeding stations in Scandinavia in June.

(ii) From the Thyne Bequest Fund:

£100 to J. A. T. Woodford (SCRI Zoology Department) attending E.P.G. Summer School Training Course, Wageningen, The Netherlands.

Full reports of these visits are available from the Secretary.

SCRI Bulletin No. 6 (August 1987)

The members of the Committee who will retire by rotation with effect from the date of the Annual General Meeting held in 1988 are Messrs C. A. Acheson, D. F. Kidd and A. Leith.

As at 31 December 1987 the membership of the Society stood at 303.

Mylnefield

1987 was not hot and not cold, not wet and not dry, nor was it windy. Taken as a whole the year was dull and damp with generally average temperatures. However, there were some exceptions to the general pattern.

Temperature

The most notable feature was that the air maximum temperature on 27 April was 22.9°C, the highest April temperature on our records and higher than the highest annual maximum in some years; indeed this year that figure was 23.4°C recorded on 16 August. Mean air and soil temperatures in June were well below average and the mean 10 cm soil temperature (12.4°C) matched the previous lowest figure recorded in 1958.

Rainfall

Although March and April were very wet there was a very dry spell 12-29 April which would have permitted timely cultivations. That spell was broken with 23 mm on 30 April and there were no significant soil moisture deficits thereafter until the end of July.

June was the wettest on our records (237% of average) and on two days, 5 and 13, there was more than 30 mm of rain.

Over the year as a whole, rainfall was 10% above average.

Sunshine and Solar Radiation

Mid-summer was dull and the durations of bright sunshine in June and July were only 77% of the long term average. The receipt of solar radiation was the lowest on our records for that month. In contrast the duration of bright sunshine in August and September was 128% of the long term average and the highest on our records for that period.

Wind

Average windspeeds were generally low and were below average in each month except September when windspeed was above but close to average. The total run-of-wind for the year was only 80% of the average, making 1987 the calmest year on our records.

Potential Evaporation

For each of the first 7 months, potential evaporation was below average. In the remainder of the year the values were close to normal.

(D. K. L. MacKerron, R. Neilson)

Pentlandfield

January was notable for a very severe spell of weather characterised by a combination of snow and very low temperatures. February and March were changeable, and not until mid-April did the weather become warm. May brought a dramatic change, with cool air from the north persisting for much of the month. Early June was dull and wet; thereafter a light showery northerly airstream persisted. July's northerly winds brought warmer but moister weather, the pattern continuing into August with some very heavy falls of rain. September continued wet but changeable with some intense sunny periods. Through October, November and December unsettled but calm weather predominated, with none of the extremely violent storms that crossed southern England.

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	3.7	−1.8	−1.3	−1.3	0.7	−0.8	2.1	−0.4	3.1	152.4	28	0.0	68.6	+ 5.8	53.8	+ 0.7	49	8.5	−4.4
February	6.1	+0.5	0.2	+0.2	1.7	+0.1	2.6	0.0	10.4	90.5	22	6.7	39.9	− 8.1	79.5	+ 7.9	108	6.1‡	−6.1
March	6.9	−1.0	0.9	−0.8	2.6	−0.7	3.7	−0.6	14.9	79.1	17	30.1	72.6	+23.7	113.3	+ 8.0	201	13.4	−1.4
April	12.7	+1.7	4.9	+1.6	7.5	+1.2	7.4	+0.5	96.7	19.4	8	52.2	66.3	+26.2	138.9	−18.5	312	12.1	−2.1
May	13.3	−0.4	5.7	−0.1	10.2	0.0	10.3	+0.2	117.2	7.9	6	79.1	42.4	−13.2	170.7	−11.5	433	11.0	−1.5
June	14.4	−2.5	8.2	−0.5	12.4	−1.5	12.4	−1.1	160.0	0.7	0	68.5	119.6	+69.3	115.1	−63.3	421	8.9	−2.9
July	18.6	+0.1	10.9	+0.7	15.3	0.0	14.8	−0.3	272.1	0.0	0	86.1	56.0	− 5.5	156.1	−18.8	409‡	9.8	−0.9
August	18.5	+0.2	10.5	+0.4	14.4	0.0	15.1	+0.2	263.6	0.5	0	79.3	66.5	+ 0.9	180.3	+26.5	391	9.3	−0.5
September	15.7	−0.2	8.0	−0.6	11.4	−0.1	13.1	+0.4	179.6	3.0	10	51.1	47.5	−15.6	167.7	+49.6	280	11.9	+0.6
October	10.9	−1.6	5.1	−1.1	7.5	−0.6	9.8	+0.1	81.6	19.3	20	15.6	99.4	+37.7	72.7	−18.0	117	8.5	−3.1
November	8.4	+0.1	3.7	+1.5	4.8	+0.7	7.2	+1.3	35.8	34.1	24	5.7	23.1	−32.9	71.2	+ 4.2	58‡	8.0	−4.1
December	7.5	+1.2	2.7	+1.9	3.6	+1.3	5.1	+1.5	30.7	60.5	19	3.4	48.7	−21.1	22.8	−21.1	25	9.7	−3.0

*DFA Deviation from 1954-83 average ‡Some values missing – mean calculated from values present †DFA Deviation from 1959-83 average

Month	Mean Air Temperature °C		Mean Soil Temperature °C		Number of Days Air Temperature °C		Total Rainfall	Number of Wet Days
	Max.	Min.	5 cm	10 cm	Air	Grass	mm	>1.0 mm
January	3.5	−1.0	0.4	0.9	15	25	49.7	10
February	5.9	0.8	1.6	1.9	12	18	35.0	7
March	6.5	0.4	2.3	2.3	14	19	78.7	10
April	12.6	4.7	8.3	7.3	0	5	54.7	6
May	11.9	4.8	10.1	9.4	0	6	43.7	10
June	14.0	7.6	13.2	12.2	0	1	79.2	13
July	18.0	10.2	15.9	14.8	0	0	76.3	9
August	17.3	9.8	14.5	13.7	0	0	120.4	17
September	15.4	7.7	11.6	11.0	0	1	39.7	10
October	10.9	4.4	7.1	7.0	1	6	77.9	13
November	7.9	3.2	4.6	4.8	4	10	46.9	11
December	7.4	2.5	3.4	3.6	9	13	45.3	13
Annual Total	—	—	—	—	55	104	747.5	129
Annual Mean	10.9	4.6	7.8	7.4	—	—	—	—

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SCRI CULTIVARS FOR WHICH NSDO HAS DEVELOPMENTAL RESPONSIBILITY

Spring barley
- Heriot
- Tweed
- Tyne

Grazing turnip
- Appin

Swede
- Angus
- Melfort

Forage rape
- Arran

Potato
- Ailsa
- Baillie
- Glenna
- Kirsty
- Morag
- Pentland Hawk
- Pentland Ivory
- Pentland Javelin
- Pentland Squire
- Provost
- Shelagh
- Shula
- Teena
- Torridon

Winter cabbage
- Celtic

Black currant
- Ben Alder
- Ben Lomond
- Ben Nevis
- Ben Sarek

Hybrid berry
- Tayberry
- Tummelberry

Raspberry
- Glen Clova
- Glen Moy
- Glen Prosen

Lily
- Pandora
- Phoebus

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
BAPB	British Association of Plant Breeders
BASIS	British Agrochemical Supply Industry Scheme
BBA	Biologische Bundesanstalt
BBC	British Broadcasting Corporation
BCPC	British Crop Protection Council
BSPP	British Society of Plant Pathology
CABO	Centrum voor Agrobiologisch Onderzoek
CEC	Commission of European Communities
CIAT	Centro Internacional de Agricultura Tropical
COSAC	Council of Scottish Agricultural Colleges
DAFS	Department of Agriculture and Fisheries for Scotland
DANI	Department of Agriculture for Northern Ireland
DSIR	Department of Scientific and Industry Research
DTI	Department of Trade and Industry.
EAPR	European Association for Potato Research
ECRE	Edinburgh Centre for Rural Economy
EEC	European Economic Community
EMBO	European Molecular Biology Organisation
EPPO	European Plant Protection Organisation
ERCC	Edinburgh Regional Computing Centre
ESCA	East of Scotland College of Agriculture
FAO	Food and Agriculture Organisation
GCIRC	Groupe Consultatif International de Recherche sur le Colza
HDC	Horticultural Development Council
IAC	International Agricultural Centre
IACR	Institute of Arable Crops Research
IAPTC	International Association for Plant Tissue Culture
IARI	Indian Agricultural Research Institute
IBMC	Institut de Biologie Moleculaire et Cellulaire
ICETEX	Institut Colombiano de Especializacion Tecnica en el Exterior
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
IFR	Institute of Food Research
IFVS	Institute for Fruit and Vegetable Science
IGAP	Institute for Grassland and Animal Production
IHR	Institute for Horticultural Research
INRA	Institut National de la Recherche Agronomique
IOBC	International Organisation for Biological Control

IOH	Institute of Horticulture
IPO	Institut voor Plantzenziektenkundig Onderzoek
IPSR	Institute of Plant Science Research
ISHS	International Society for Horticultural Science
MAFF	Ministry of Agriculture, Fisheries and Food
MISR	Macaulay Institute for Soil Research
MLURI	Macaulay Land Use Research Institute
NERC	Natural Environment Research Council
NFU	National Farmers Union
NIAB	National Institute of Agricultural Botany
NPTC	National Proficiency Test Council
NSCA	North of Scotland College of Agriculture
NSDO	National Seed Development Organisation
ODA	Overseas Development Administration
ORSTOM	Office de la Recherche Scientifique et Technique d'Outre Mer
PMB	Potato Marketing Board
RMS	Royal Microscopical Society
SAC	Scottish Agricultural Colleges
SASS	Scottish Agricultural Statistics Service
SARI	Scottish Agricultural Research Institutes
SCRI	Scottish Crop Research Institute
SEB	Society for Experimental Biology
SERC	Science and Engineering Research Council
SGM	Society for General Microbiology
SNSA	Scottish Nuclear Stocks Association
SSCR	Scottish Society for Crop Research
SSPDC	Scottish Seed Potato Development Council
SVP	Studiekring voor Plantenveredeling
UCLA	University of California Los Angeles
UCSD	University of California San Diego
UK	United Kingdom
USA	United States of America
USSR	Union of Soviet Socialist Republics
WMO	World Meteorological Organisation
WSAC	West of Scotland Agricultural College

Miscellaneous

CASE	Cooperative Awards in Science and Engineering
CHIP	Computer Housed Information Package
CPC	Commonwealth Potato Collection
DM	Dry matter
EHF	Experimental Husbandry Farm
EHS	Experimental Husbandry Station
ELISA	Enzyme linked immunosorbent assay
EM	Electron microscope
EMAS	Edinburgh Multiple Access System
EPG	Electrical penetration graph
FPLC	Fast protein liquid chromatography
GLC	Gas liquid chromatography
GMT	Greenwich Mean Time
HPLC	High pressure liquid chromatography

IFS	Increased Flexibility Scheme
ISEM	Immunosorbent electron microscopy
JMT	Joint Main Trials
NFT	National Fruit Trials
NIR	Near infra-red
NLT	National List Trials
PCN	Potato cyst nematode
PDA	Potato dextrose agar
PYO	Pick-your-own
RCCA	Research Council Co-operative Award
RH	Relative humidity
SEM	Scanning electron microscope
SMCO	S-methyl cysteine sulphoxide
TGA	Total glycoalkaloid
u.v.	Ultra violet

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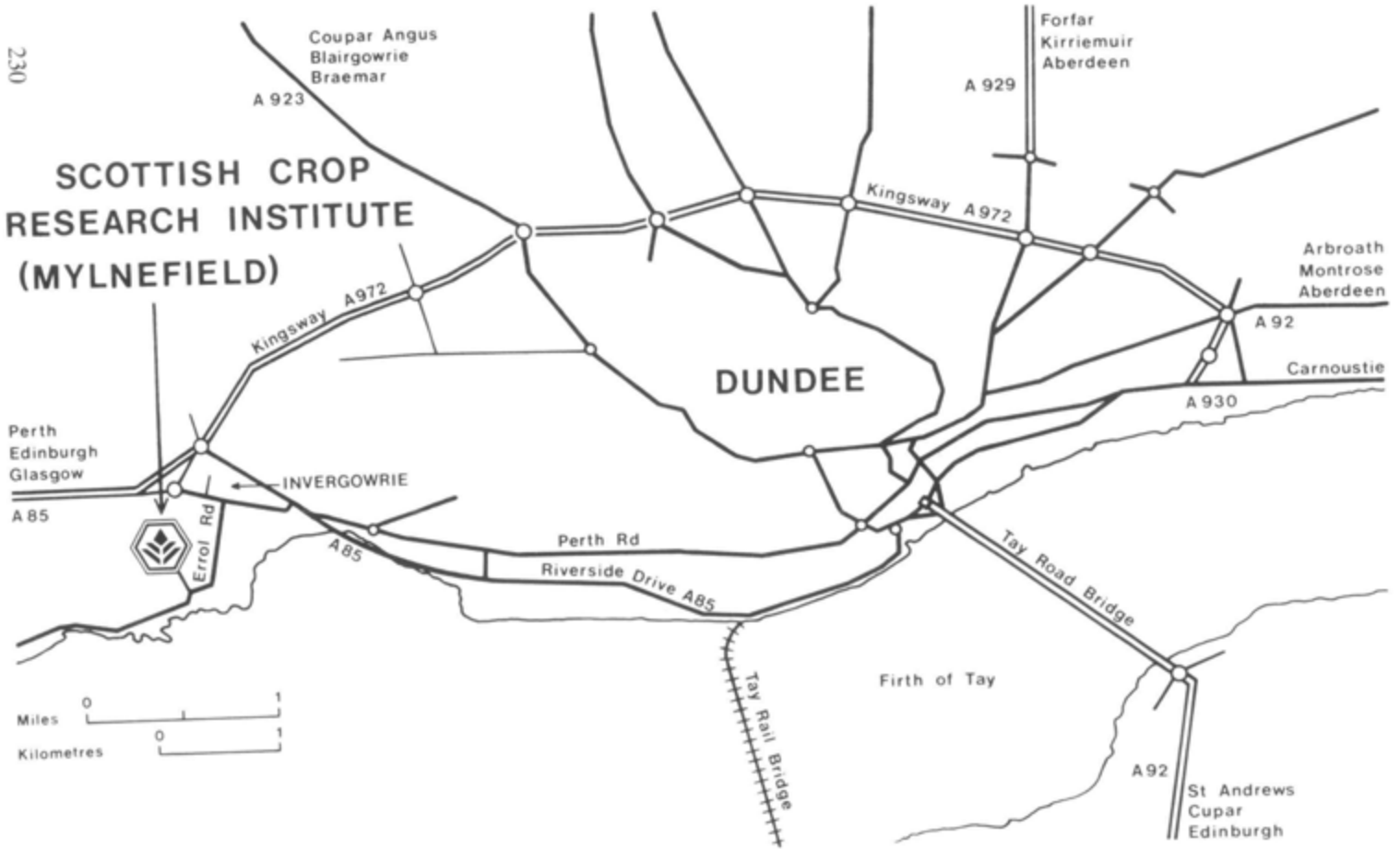
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